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OF THE

NORTH-EAST COAST INSTITUTION

OF

ENGINEERS AND SHIPBUILDERS.

EDITED BY THE SECRETARY OF THE INSTITUTION.

VOLUME XI.

ELEVENTH SESSION, 1894-95.

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Vice-Presidents:

J. R. Fothergill.
John Gravell.
Sir William Gray.
W. Kilvington.
Arthur Laing.
Hugh Macoll.
Magnus Sandison.
Alex. Taylor.
R. L. Weighton, M.A.

Honorary Treasurer:—G. E. Macarthy.

Councilmen:

Edwin W. De Rusett.
Charles D. Doxford.
Henry Fownes.
W. Hök.
M. C. James.
W. C. Mountain.
Thomas Mudd.
James Patterson.
Joseph M. Rennoldson.
Herbert B. Rowell.
Anton. G. Schaeffer.
G. W. Sivewright.
W. G. Spence.
J. C. Stirzaker.
J. E. Stoddart.

Assistant Librarian:—H. S. Wallace.

Secretary and Treasurer:—John Duckitt.

Graduate Section:

Chairman—Alfred L. Forster.

Hon. Secretary—C. T. Adams.

Committee:

Ernest Baker.
Talbot Duckitt.
Hugh Laing.
E. F. Moroney.
E. T. White.

Offices and Reading Room:

4, St. Nicholas' Buildings West, Newcastle-upon-Tyne.

COMMITTEES.

ELEVENTH SESSION, 1894–95.

Finance Committee:

WILLIAM BOYD (Chairman).

J. GRAVELL.
A. LAING.
HUGH MACOLL.
W. C. MOUNTAIN.
JAMES PATTERSON.
G. E. MACARTHY (Hon. Treasurer).

Reading Committee:

E. W. DE RUSETT.
M. C. JAMES.
J. PATTERSON.
H. ROWELL.
A. G. SCHAEFFER.
W. G. SPENCE.

Library Committee:

W. COOPER.
W. HÖK.
W. C. MOUNTAIN.
J. C. STIRZAKER.
R. L. WEIGHTON, M.A.

Statistical Committee:

J. GRAVELL.
A. LAING.
HUGH MACOLL.
J. F. WALLIKER.

Representatives on Lloyd's Sub-Committee:

WILLIAM BOYD.
F. C. MARSHALL.
ROBERT THOMPSON.
HENRY WITHY.

Representative on Council of Durham College of Science:

JOHN GRAVELL.

Representatives on Sub-Committee of Northumberland County Technical Education Committee:

ALEXANDER TAYLOR.
GEORGE E. MACARTHY.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

List of Members, July, 1895.

EXPLANATION.

(A.)	Agent and Accountant.	(I. & S. M.)	Iron and Steel Merchants and Manufacturers.
(B. B.)	Boiler Builder.	(M. S.)	Marine Superintendent.
(C. E.)	Civil and Consulting Engineer.	(N. A.)	Naval Architect.
(E.)	Engineer and Boilermaker.	(R. M.)	Rope Manufacturer.
(E. A.)	Engineering Agent.	(S.)	Shipbuilder.
(E. E.)	Electrical Engineer.	(S. O.)	Ship Owner.
(F. M.)	Forge Master.	(SUR.)	Engineer & Ship Surveyor.

HONORARY MEMBERS.

ELECTED.

The Right Hon. Lord Armstrong, C.B., D.C.L., F.R.S., Cragside, Rothbury ... ... Nov. 1884

The Right Honourable the Earl of Ravensworth, Ravensworth Castle, near Gateshead-on-Tyne... ... ... Nov. 1884

Sir W. H. White, C.B., LL.D., F.R.S., The Admiralty, Whitehall, London ... ... (N A) Nov. 1884

MEMBERS.

A.

Abey, Henry, Fairfield, York Road, West Hartlepool ... ... (E) Jan. 1889

Adamson, Alex., c/o Messrs. Naval Construction and Armaments Co., Barrow-in-Furness ... ... (S) Nov. 1885

Adamson, Cumberland, 3, Close Street, Sunderland ... ... (S) Nov. 1893

Adamson, Daniel, c/o Messrs. Joseph Adamson & Co., Hyde, Cheshire ... ... (E) { Graduate, Feb. 1888; Member, Oct. 1894

Alchin, A. H., Uxbridge Road, London, W. ... ... (E) Jan. 1885

Alder, Sydney, Edinbro' Buildings, South Shields ... ... (C E & N A) Nov. 1893

Allan, Jas. McNeal, 3, Parkville, Heaton, Newcastle-on-Tyne ... (E) Dec. 1886

Allardes, Wm., c/o Messrs. Harland & Wolff, Ltd., Engine Works, Belfast ... ... (E) Nov. 1884

Ampuero, Bernardo, Chief of the Chilian Cruiser "Presidenta Pinto," Circulo Naval, Valparaiso ... ... (E) Mar. 1894

Anderson, Joseph, c/o Messrs. Wigham Richardson & Co., Neptune Works, Walker-on-Tyne ... ... (E) Nov. 1884

Andrew, D., 33, Osborne Road, Jesmond, Newcastle-on-Tyne ...(SUR) Jan. 1885

Andrews, Jas., Drawing Office, Messrs. Naval Construction and Armaments Co., Barrow-in-Furness ... ... (E) Nov. 1884

ELECTED.

Angus, W. J., 9, Ibrox Place, Govan, Glasgow ... ... (E) Oct. 1892
Anthony, Jas., 6, Northumberland Square, North Shields... ... (S) Oct. 1886
Archbold, Joseph G., c/o Messrs. Blyth Dry Dock Co., Blyth ... (E) Jan. 1889
Archbold, William, c/o Messrs. Ernest Scott, Mountain, & Co., The Close, Newcastle-on-Tyne ... ... (E) Mar. 1894
Armstrong, G. S., c/o Mrs. Witcher, South Town, Dartmoor ... (S) Nov. 1884
Armstrong, Joseph, 27, Ripon Street, Sunderland ... ... (S) Nov. 1892
Armstrong, Robert B., 26, Warwick Street, Heaton, Newcastle-on-Tyne ... ... (E) Oct. 1887
Armstrong, William S., 8, Friedrickstrasse, Kiel, Germany (S) { Graduate, Oct. 1892; Member, April 1895
Arnison, Geo., Jun., 61, Fawcett Street, Sunderland (N A & SUR) Nov. 1884
Atherton, William Henry, 47, Lovaine Place, Newcastle-on-Tyne (E) Oct. 1891
Atkinson, F. C., 37, Croydon Road, Newcastle-on-Tyne ... ... (E) Dec. 1892
Atkinson, John Joseph, 7, Swiss Road, Elm Park, Fairfield, Liverpool ... ... (E) Mar. 1891
Austin, W. R., Lloyd's Register of Shipping, Royal Exchange, Middlesbrough ... ... (E SUR) Oct. 1888
Ayre, James Reay, 16, Neptune Road, Wallsend-on-Tyne ... ... (S) Jan. 1894

B.

Bagnall, T. W., The Groves, Winlaton-on-Tyne ... ... (F M) Nov. 1893
Baguley, Ernest Edwin, Lyndhurst, Rowley Park, Stafford ... (E) April 1891
Bailey, James, 3, South Avenue, Ryton-on-Tyne ... ... (E) Nov. 1884
Baines, Geo. Henry, Messrs. Central Marine Engineering Co., West Hartlepool ... ... (E) Oct. 1888
Baird, George, 22, Lovaine Place, North Shields ... ... (E) Oct. 1892
Baird, Robert, 13, Hylton Terrace, North Shields ... ... (E) Jan. 1890
Barclay, James, Lloyd's Register of Shipping, Swansea ... ...(SUR) Nov. 1888
Barley, C. J., c/o Messrs. The Kensington and Knightsbridge Electric Lighting Co., Chapel Place, Brompton Road, London, S.W. ... ... (E) { Graduate, Feb. 1885; Member, Dec. 1886
Barnett, James Rennie, Lilybank House, Johnston, N.B.... ... (S) Oct. 1889
Barnsley, John, Field House West, North Shields ... ... (E) May 1892
Barron, T. G., Fern Villas, Elwick Road, West Hartlepool ... (E) Oct. 1888
Barrow, A. R., c/o Messrs. William Watson & Co., 28, Apollo Street, Bombay, India ... ... (E) Feb. 1891
Batey, John Thomas, 25, Harrison Place, Newcastle-on-Tyne ... (S) Nov. 1885
Batliboi, Jehangir Framji, 71, Apollo Street, Fort, Bombay ... (E) Dec. 1888
Baxter, J., 26, Simonside Terrace, Heaton, Newcastle-on-Tyne ... (E) Nov. 1884
Beadon, D. C., 68, Park Road, Newcastle-on-Tyne ... ... (E) Jan. 1885
Bell, Geo. Arthur, 48, Crown Street, Newcastle-on-Tyne (E) { Graduate, Oct. 1890; Member, Jan. 1894
Bell, Robert Turner ... ... (S) Oct. 1891
Bell, William, West Wing, Point Pleasant, Wallsend-on-Tyne ... (E) Nov. 1888
Bell, William, 5, Grey Place, Greenock ... ... (S) April 1893
Bergström, Gus., Bergsund, Stockholm ... ... (N A) Mar. 1886
Berkley, A. B., Kent Villas, Jarrow-on-Tyne ... ... (E) Mar. 1887
Bigge, D. L. Selby, 27, Mosley Street, Newcastle-on-Tyne... ... (E E) Nov. 1894

ert, Geo. A., Wellington Villa, St. Luke's, Cork ... ... (E) Nov. 1893
a. Nusserwanji Bomanji, Sleaton Road, Tardeo, Bombay, British India ... ... (E) Dec. 1888
meron, Angus, c/o James Laing, Esq., Deptford Yard, Sunderland (S) Nov. 1892
meron, David, 11, Graham Place, Dundee ... ... (E) April 1891
meron, Henry, Hazlebank, Trinity, Edinburgh ... ... (E) Oct. 1892
mpbell, J. Jennings, Bureau Veritas, 155, Fenchurch Street, London, E.C. ... ... (E) Oct. 1888
Campbell, John M., 4, Winchester Terrace, Newcastle-on-Tyne ... (N A) April 1895
Campbell, Thomas, c/o Messrs. Hills Dry Dock Co., Cardiff ... (S) Mar. 1894
Camps. H. E. J., 2. Kent Villas, Kent Street, Jarrow-on-Tyne ... (N A) Oct. 1894
Cannell, Frank, Messrs. H. Parry & Son, Lisbon ... ... (E & S) Nov. 1887
Carruthers, Frank, 27, Fenham Road, Newcastle-on-Tyne... ... (E) Nov. 1893
Carstons, Samuel, Messrs. Burmeister & Wains, Maskin-og Skibsbyggeri, Copenhagen, Denmark... ... ... (S) Dec. 1887
Casey, James, 10, Philpot Lane, London, E.C. ... ... (E) Nov. 1891
Cay, Arthur, Messrs. Cay, Hall, & Co., Quayside, Newcastle-on-Tyne... ... ... (E) Nov. 1884
Ceuvel, John L., Kantoor, Gebouw, Amsterdam ... ... (E) Mar. 1886
Chandler, Noel, Messrs. Bumsted & Chandler, Cannock Chase Engine Works, Hednesford, Staffordshire ... ... (E) Oct. 1891
Chapman, Abel, Capt., Belle Vue, Low Fell, Gateshead-on-Tyne (E) Nov. 1884
Chapman, Harry Reynolds, Messrs. Clarke, Chapman, & Co., Gateshead-on-Tyne ... ... (E) Mar. 1893
Chapman, Hedley, 147, Park Road, Newcastle-on-Tyne ... ... (E) Feb. 1886
Charlton, Henry, 1, Millfield Terrace, Gateshead-on-Tyne ... (E) Nov. 1884
Charlton. R. B., Jun., Manors Railway Station Works, Newcastle-on-Tyne ... ... (E) Nov. 1884
Charlton, T., 25, Lincoln Street. Gateshead-on-Tyne ... ... (E) Nov. 1884
Charlton, Thomas, The Cedars, Millhill, West Cowes, Isle of Wight (E) Nov. 1890
Chaston, Edward Catmore, 45, Cardigan Terrace, Heaton, Newcastle-on-Tyne ... ... (E) Oct. 1894
Cherry, Thos. Wm. Fry, c/o Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's, Newcastle-on-Tyne ... ... (E) Oct. 1894
Chicken, Thomas, c/o Messrs. Newport Engineering and Ship Repairing Co., Newport. Monmouth ... ... (E) Oct. 1892
Chisholm, Alexander, 2, Kent Villas, Kent Street, Jarrow-on-Tyne (S) Mar. 1893
Christie, C. J. D., Neptune Works, Walker-on-Tyne ... ... (S) Nov. 1884
Christie, J. D., 4, Colbeck Terrace, Tynemouth ... ... (S) Nov. 1884
Churchill, James Dixon, 9, London Street, London, E.C.... ... (E) Oct. 1889
Clague, James Henry, Birkenhead Iron Works, Birkenhead ... ... (S) { Graduate, April 1891; Member, May 1894
Clark, Geo., Southwick Engine Works, Sunderland ... ... (E) Nov. 1884
Clark, George, Jun., Southwick Engine Works, Sunderland ... (E) Feb. 1888
Clark, Henry, Southwick Engine Works, Sunderland ... ... (E) Oct. 1887
Clark, James Carver, 5, Rium Terrace, West Hartlepool ... ... (E) Nov. 1892
Clarke, Henry Trevisa, Deptford Shipyard, Deptford, Sunderland (S) Mar. 1892
Cohn, William M., 2. Marine Terrace, North Shields ... ... (S) Nov. 1893
Coleby, James W., Carlyle Street, Willington Quay-on-Tyne ... ... (E) { Graduate, Oct. 1891; Member, Jan. 1894

		ELECTED
Dick, Francis, 6, Gladstone Street, Sunderland	(E)	Nov. 1885
Dick, F. W., c/o Messrs. Palmer's Shipbuilding Co., Jarrow-on-Tyne...	(I & S M)	Oct. 1891
Dickie, James, 428, Mississippi Street, Poturo, San Francisco, California, U.S.A....	(S)	Mar. 1894
Dickinson, F. T., 23, Park Place W., Sunderland ...	(E)	Graduate, May 1885 Member, Oct. 1886
Dickinson, James, The Cloisters, Sunderland	(E)	Nov. 1884
Dickinson, John, Park House, Sunderland	(E)	Nov. 1884
Dickinson, W., Park House, Sunderland	(E)	Nov. 1884
Dietze, F. G., Messrs. The Hamburg South American Steam Ship Company, Hamburg	(E)	Nov. 1893
Dixon-Brown, L. D., 42, Burdon Terrace, Newcastle-on-Tyne ...	(S)	Nov. 1886
Dixon, James, Wincomblee, Walker-on-Tyne	(S)	Dec. 1893
Dixon, John Rochester, 79, Osborne Road, Newcastle-on-Tyne	(E)	Graduate, Oct. 1887 Member, Feb. 1893
Dixon, Sir Raylton, Cleveland Shipyard, Middlesbrough	(S)	Feb. 1888
Dixon, William, Heaton Hall Road, Heaton, Newcastle-on-Tyne ...	(E)	Nov. 1893
Dobson, William, Shipbuilder, Walker-on-Tyne	(S)	Nov. 1888
Donald, George Gray, 2, South Preston, North Shields	(E)	Oct. 1890
Donald, James, 48, St. Luke's Terrace, Pallion, Sunderland ...	(S)	Nov. 1884
Donkin, George, St. Andrew's Engine Works, Newcastle-on-Tyne	(E)	Oct. 1892
Donovan, J. W., 5, Ash Place, Newcastle Road, Sunderland ...	(E)	April 1885
Dos Santos, Apolinaris J., Rio Grande-do-Sul, Brazil ...	(SUR)	Nov. 1891
Douglas, John F., c/o Messrs. Ramage & Ferguson, Leith... ...	(E)	Jan. 1888
Douglass, William, Globe Iron Works, Winlaton-on-Tyne... ...	(E)	Nov. 1893
Downing, Nicholas, Oxford Terrace, Norton Road, Stockton-on-Tees	(I F)	Oct. 1894
Dowsen, Chas., 21, Croft Terrace, Jarrow-on-Tyne...	(E)	Dec. 1885
Doxford, Albert Ernest, B.A., 2, West Lawn, Sunderland	(E)	Graduate, Oct. 1890 Member, Nov. 1893
Doxford, Charles D., Bainbridge Holme, Tunstall Road, Sunderland	(S)	Nov. 1884
Doxford, R. P., Pallion Engine Works, Sunderland	(E)	Nov. 1884
Doxford, W. Theodore, M.P., Pallion Shipyard, Sunderland ...	(S)	Nov. 1884
Drake, William Edward, 7, Rodwell Terrace, Weymouth	(E)	Feb. 1893
Drakenberg, J. A., 73, Nybrogatan, Stockholm, Sweden	(E)	Feb. 1886
Duckitt, Jno., 4, St. Nicholas' Buildings West, Newcastle-on-Tyne	(E)	Nov. 1884
Dudgeon, F. S., 30, Great St. Helens, London, E.C.	(E)	Feb. 1885
Dugdale, William H., Green Bank, Jarrow-on-Tyne	(S)	Mar. 1894
Duguid, Robert, c/o Messrs. Harland & Wolff, Belfast	(S)	Oct. 1892
Duncan, George Thos., c/o Messrs. Tangyes Limited, 3, St. Nicholas' Buildings, Newcastle-on-Tyne	(E)	Nov. 1894
Dunlop, William, 6, Chatsworth Terrace, Barrow-in-Furness ...	(E)	Mar. 1888
Dyer, Charles M. B., Lloyd's Register of Shipping, 3, St. Nicholas' Buildings, Newcastle-on-Tyne	(E SUR)	Oct. 1892
Dykes, George, Lloyd's Register of Shipping, Steinhoeft 3, Hamburg	(S)	Jan. 1893
Dykes, James, 27, Belgrave Terrace, Newcastle-on-Tyne	(E)	May 1885
Dykes, John, Lloyd's Register of Shipping, Oriel Chambers, Liverpool	(SUR)	Oct. 1889

ELECTED.

Foley, Wm. C. le B., Box 537, *Newport News*, Virginia, U.S.A. ... ... (S) { Graduate, Nov. 1887 / Member, Oct. 1892
Ford, David, c/o Mr. Gibson, 1, Jamaica Street, Glasgow ... ... (E) May 1891
Forster, William, c/o Messrs. Dixon, Robson, & Co., 2, Collingwood Street, Newcastle-on-Tyne ... ... (E) Mar. 1890
Foster, Henry, c/o Messrs. Galloway & Co., Knott Mills Ironworks, Manchester ... ... (E) April 1885
Fothergill, J. R., Dock Office, West Hartlepool ... ... (C E) Mar. 1886
Fowell, Ridley, Lloyd's Register of Shipping, Dock Office, West Hartlepool ... ...(S & E SUR) Feb. 1893
Fowling, Charles, Lloyd's Register of Shipping, Dock Office Buildings, West Hartlepool ... ... (S) Nov. 1892
Fownes, Henry, Tyne Forge, Ouseburn, Newcastle-on-Tyne ... (F M) Nov. 1884
Fox, Samson, Messrs. The Leeds Forge Co., Leeds (*Life Member*) (E) Dec. 1887
Fox, William, 9, Winfield Terrace, Chester Road, Manchester ... (E) April 1895
Franki, J. P., c/o Messrs. Morts Dry Dock and Engineering Co., Sydney, N.S.W., Australia ... ... (E) Jan. 1886
Fraser, John Imbrie, 13, Sandyford Place, Glasgow... ... ... (E) Oct. 1891
Fraser, Thomas S., Messrs. Ernest Scott, Mountain & Co., The Close, Newcastle-on-Tyne ... ... (E E) Jan. 1894
Freeman, Alfred Isaac, 2, Regent Terrace, Newcastle-on-Tyne ... ... (E) { Graduate, Dec. 1890 / Member, Nov. 1893
Furneaux, J. B., Victoria Engine Works, Gateshead-on-Tyne ... (E) Nov. 1885
Furse, Fred., Villa Schlaepfer, Capodimonte, Naples ... ... (S) April 1887

G.

Gad, Oscar, Detpford Shipyard, Deptford, Sunderland ... ... (S) Nov. 1893
Gaine, Roger L., 62, Harrison Street, Barrow-in-Furness (E) { Graduate, Dec. 1887 / Member, Oct. 1894
Gannaway, H. G., 11, Kent Street, Jarrow-on-Tyne ... ... (S) Nov. 1884
Garthwaite, John R., c/o Messrs. R. Ropner & Sons, Stockton-on-Tees (S) May 1889
Gayner, Robt. H., Jun., Beech Holm, Sunderland ... (E) { Graduate, Mar. 1886 / Member, Oct. 1888
Gearing, Ernest George, Penshurst, Clarence Drive, Harrogate ... (E) Dec. 1892
Geddes, Christopher, 2A, Drury Lane, Water Street, Liverpool ... (E) Oct. 1888
Gibson, H., 162, Roker Avenue, Monkwearmouth, Sunderland ... (S) Nov. 1884
Gibson, J. Hamilton, 12, Bratlan Road, Birkenhead (E) { Graduate, April 1891 / Member, Oct. 1894
Gibson, John W., 1, Bellerby Terrace, West Hartlepool ... ... (B B) Nov. 1891
Gibson, W. H., 37, Tatham Street, Sunderland ... ... (E) Nov. 1884
Gordon, William James, c/o Messrs. Naval Construction and Armaments Co., Barrow-in-Furness ... ... (E) Oct. 1887
Gordon, William Leslie, Invermark, Broughty Ferry, N.B. ... (E) April 1893
Graham, Edwin, Messrs. Osbourne, Graham, & Co., Hylton, Sunderland... ... ... (S) Nov. 1884
Graham, William, Ford Lodge, South Hylton, near Sunderland ... (S) Nov. 1884
Graham, William, West House, Tynemouth ... ... (S) Oct. 1891
Graham, William, Los Astilleros del Nervion, Bilbao, Spain ... (S) April 1893
Graham, William, Primrose Villa, Kingsland Crescent, Barry Docks, South Wales ... ... (E) Nov. 1894

ELECTED.

Harvey, John W. J., 1, Richmond Villa, Chertsey Road, Redland, Bristol ... ... (E) Feb. 1889
Havelock, Michael, G, Exchange Buildings, King Street, Newcastle-on-Tyne ... ... (E) Dec. 1887
Head, Archibald P., 47, Victoria Street, London, S.W. (E) { Graduate, Nov. 1884 / Member, Oct. 1887
Headlam, Robert, New Park Terrace, Hartburn Lane, Stockton-on-Tees ... ... (E) Nov. 1886
Heck, John H., Lloyd's Register of Shipping, Newport, Monmouthshire... ... ... (S SUR) Nov. 1885
Henderson, Alex., c/o Messrs. Empreza, Nacional, De. Nav. D'Vapor, Lisbon ... ... (E) April 1893
Henderson, A. M., 3, Greatham Terrace, West Hartlepool ... (E) Nov. 1890
Henderson, George, 54, Westmorland Road, Newcastle-on-Tyne... (E) Nov. 1884
Henderson, Robert, 30, Lovaine Crescent, Newcastle-on-Tyne ... (S) Nov. 1884
Henshall, Samuel, c/o Messrs. Sir Raylton Dixon & Co., Cleveland Shipyard, Middlesbrough ... ... (S) { Graduate, May 1885 / Member, Jan. 1894
Hepburn, Alfred, Northumberland Forge, Wallsend-on-Tyne ... (F M) Dec. 1890
Hepple, William, Slipway, South Shields ... ... (E & S) Oct. 1885
Hepple, William Thos., Messrs. Hepple & Co., Engineers, Wapping Street, South Shields ... ... (E) Dec. 1893
Hildrey, A. J., 28, Rosslyn Terrace, Sunderland ... ... (S) Nov. 1884
Hill, Alfred William, Otterburn Terrace, Newcastle-on-Tyne ... (I M) Oct. 1891
Hill, Maxwell, 2, The Side, Newcastle-on-Tyne ... ... (N A) Nov. 1884
Hindson, William, Bensham Lodge, Gateshead-on-Tyne ... ... (E) Nov. 1884
Hindson, William Forster, 7, Elysium Lane, Bensham, Gateshead-on-Tyne... ... ... (E) { Graduate, Nov. 1891 / Member, Nov. 1892
Hines, William, R.N., 57, St. Andrew's Road, Southsea ... ... (E) Mar. 1890
Hirst, Richard, Lloyd's Register of Shipping, Dock Offices, West Hartlepool ... ... (E SUR) Nov. 1885
Hodge, Rowland F. W., Messrs. C. S. Swan & Hunter, Wallsend-on-Tyne ... ... (S) Dec. 1890
Hogg, James, 8, Lovaine Terrace, North Shields ... ... (B F) Nov. 1889
Hök, Wilhelm, Deptford Shipyard, Sunderland ... ... (S) Oct. 1886
Holbrook, Thomas, 22, St. Hilda Street, Hartlepool ... ... (E) Nov. 1893
Holgate, Charles H., Cardigan Villa, Grove Lane, Headingley, Leeds ... ... (E) Feb. 1895
Hollis, Henry William, Whitworth House, Spennymoor ... ... (I M) Oct. 1891
Holmes, John H., Portland Road, Newcastle-on-Tyne ... ... (E E) Jan. 1888
Homji, A. C. N., 13, Trinity Street, Dhobie, Talao, Bombay, India (E) Nov. 1884
Hooper, Ernest, 23, Whitehall Terrace, Sunderland ... ... (E) Nov. 1885
Hopkinson, Frank A., c/o Messrs. J. Hopkinson & Co., Huddersfield (E) Dec. 1891
Houston, John, 32, Randolph Street, Sunderland ... ... (E) Nov. 1894
Hunter, George B., Messrs. C. S. Swan, Hunter, & Co., Wallsend-on-Tyne ... ... (S) Nov. 1884
Hunter, J. W., Pendleton House, Stockton Road, Sunderland ... (E) May 1885
Hunter, Summers, c/o Messrs. N.E. Marine Engineering Co., Northumberland Engine Works, Wallsend-on-Tyne... ... (E) Nov. 1885
Hutchinson, C. W., 6, Park Parade, Westmorland Road, Newcastle-on-Tyne ... ... (E) Nov. 1884
Hutchinson, Wesley, B.A., 6, Park Parade, Newcastle-on-Tyne ... (E) Oct. 1891

ELECTED.

Hutchison, J., Board of Trade Offices, Middlesbrough ... ...(SUR) Dec. 1891
Hutchison, Thomas Allan, 22, Wharncliffe Street, Newcastle-on-Tyne ... ... (S) Nov. 1891

I.

Inglis, John, c/o Messrs. Hawthorn & Co., Leith ... ... (S) April 1887
Inglis, John, Pointhouse Shipyard, Partick, Glasgow ... (E & S) Oct. 1886
Inman, Douglas S., 17, Wandsworth Road, Heaton, Newcastle-on-Tyne ... ... (E) Oct. 1892
Irwin, J. H., Sunderland Engine Works, South Docks, Sunderland (E) Nov. 1884
Irwin, Thomas F., 1, St. Alban's Road, Bootle, near Liverpool ... ...(C E & N A) Mar. 1888

J.

Jack, William C., Service Subventionné des Correspondances Fluviales au Tonkin, Haiphong, China ... ... (E) Nov. 1894
Jackson, A., Surveyor's Office, Board of Trade, North Shields (E SUR) Nov. 1888
Jackson, Herbert Stonewall, c/o Messrs. Westgarth, English, & Co., Middlesbrough ... ... (E) Dec. 1891
Jackson, Vincent, 5, Beaconsfield Street, Hartlepool ... ... (S) April 1888
Jackson, William S., Messrs. Gourlay Bros. & Co., Camperdown Shipyard, Dundee... ... ... (S) April 1891
James, M. C., 18, Denmark Street, Gateshead-on-Tyne ... ... (S) Nov. 1884
Jameson, John T., 3, The Grove, Sunderland ... ... (E) Nov. 1885
Jeffrey, Philip, 98, Park Road, Newcastle-on-Tyne... ... ... (E) Dec. 1892
Jobling, J. C., Blackwall Ironworks, Isle of Dogs, London, E. ... (E) Nov. 1884
Jobling, W. J., 1, Akenside Hill, Newcastle-on-Tyne ... (E & S O) Nov. 1884
John, Edmund, Barry Dock, Cardiff ... ... (E) Dec. 1889
Johnson, Alexander, 34, Cardigan Terrace, Heaton, Newcastle-on-Tyne ... ... (E) Feb. 1892
Johnson, Johan, 7, Vestra Hamngaten, Gothenburg, Sweden ... (S) May 1885
Johnson, T. Allan, Dry Docks, Passage West, Cork ... ... (S) Nov. 1884
Johnstone, William, Lloyd's Register of Shipping, Barrow-in-Furness ... ...(SUR) Nov. 1884
Joicey, Jacob G., Forth Banks West Factory, Newcastle-on-Tyne (E) Jan. 1889
Jones, George, c/o Messrs. W. Gray & Co., West Hartlepool ... (S) Oct. 1888
Jones, Morlais G., 6, Delahay Street, Westminster, London, S.W.

K.

Keene, H. R., Lloyd's Register of Shipping, 2, White Lion Court, Cornhill, London, E.C. ... ... (E) { Graduate, May 1885; Member, April 1887 }
Kelsey, William, 4, Lily Avenue, Jesmond, Newcastle-on-Tyne ... (E) Dec. 1893
Kendall, Stonard O., Lloyd's Register of Shipping, Glasgow (SUR) Mar. 1891
Kerfoot, James, 7, Queen's Terrace, Jesmond, Newcastle-on-Tyne (E) Oct. 1892
King, Donald, 22, Rothesay Gardens, Partick, Glasgow ... ... (E) Jan. 1890
King, John, 15, Nesham Street, Newcastle-on-Tyne... (S) { Graduate, Dec. 1890; Member, Oct. 1892 }
Kirkaldy, John, 40, West India Dock Road, London ... ... (E) Nov. 1885
Kitching, J. F., 4, Hart Road, West Hartlepool ... ... (E) Nov. 1890
Knaffl, Alvis, c/o Norddeutscher Lloyd, Bremerhaven ... ... (E) Mar. 1893

ELECTED.

L.

Laidley, R. W., 56, Pitt Street, Sydney, N.S.W., Australia ... (E) April 188
Laing, Andrew, Fairfield Works, Govan, Glasgow ... ... (E) Oct. 189
Laing, Arthur, Deptford Shipyard, Sunderland ... ... (S) Nov. 188
Laing, John, c/o Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's, Newcastle-on-Tyne ... ... (E) Nov. 1884
Larkin, James, Simonside Terrace, East Jarrow-on-Tyne ... ... (E) Nov. 1884
Lewis, R. A., Newburn Steel Works, Newburn-on-Tyne ... ... (E) Nov. 1884
Liddell, J., c/o Messrs. Denny & Co.. Engine Works, Dumbarton (E) Nov. 1884
Lie, Gotfred, Det Bergenske Dampskibsselskab, Bergen ... ... (E) Jan. 1895
Lindfors, Hugo, 16, Alexandersgatan, Helsingfors, Finland (SUR) May 1889
Lineham, Wilfrid J., Jesmond, Leyland Road, Lee, London, S.E. (E) Oct. 1890
List, John, Orchard House Works, Blackwall, London, E. ... (E) April 1891
Littleboy, Chas. Wm., 2, Lorne Terrace, Stockton-on-Tees ... (S) Oct. 1887
Livingston, Thos. L., Dunedin House, Jarrow-on-Tyne ... ... (S) Nov. 1884
Lohmeyer, H., 43, Crown Street, Newcastle-on-Tyne ... ... (E) Nov. 1884
Long, A. E., 124, Albert Road, Jarrow-on-Tyne ... ... (S) Nov. 1884
Lowdon, David. Messrs. The Barry Dock, Cardiff ... ... (E) May 1894
Lowdon, John, Messrs. The Barry Graving Dock and Engineering Co., Limited, Barry Dock, near Cardiff ... ... (E) Dec. 1891

M.

MacColl, Hector, Strandtown, Belfast ... ... (E) Dec. 1890
Maccoy, John, 55, Larkspur Terrace, Newcastle-on-Tyne ... ... (E) Feb. 1886
MacDonald, David R., c/o Messrs. Sir W. G. Armstrong, Mitchell, & Co., Walker Shipyard, Newcastle-on-Tyne ... ... (S) Nov. 1891
Mace, W., 253, Albert Road, Jarrow-on-Tyne ... ... (E) Jan. 1886
Macfarlane, Andrew, 18, John Street, Sunderland ... ... (E) Dec. 1890
MacGregor, John, 2, Michaelston Villas, Barrow-in-Furness ... (E) Mar. 1888
MacHaffie, John, 635, Terrace Place, Schenectady, New York, U.S.A. (E) Dec. 1885
Mackay, William, 11, Kilbirnie Cottages, Clydebank, Glasgow ... (S) Mar. 1892
Macmillan, Walter ... ... (E) May 1891
Macoll, Hugh, 4, Azalea Terrace North, Sunderland (*Life Member*) (S) Nov. 1884
Mair, James, Wh. Sc., 39, Dockwray Square, North Shields ... (E) Oct. 1894
Manaira, Guiseppe, 4, Salita S Gerslamo, Genoa, Italy ... (E & N A) Nov. 1893
Marlborough, Richard, 44, Muirpark Gardens, Partick, Glasgow... (S) Nov. 1884
Marr, James, 6, Ash Place, Sunderland ... ... (S) Nov. 1884
Marshall, F. C., 38, Percy Gardens, Tynemouth ... ... (E) Nov. 1884
Marshall, Frank T., Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's, Newcastle-on-Tyne ... ... (E) Graduate, Jan. 1885; Member, Oct. 1888
Marshall, R. J., 51, Larkspur Terrace, Jesmond, Newcastle-on-Tyne (E) Mar. 1887
Mastaglio, W. D., 65, Warrington Road, Newcastle-on-Tyne ... (E) Nov. 1885
Mather, Charles, 44, Warrington Road, Newcastle-on-Tyne ...(SUR) Oct. 1888
Matheson, William, c/o Messrs. R. & W. Hawthorn, Leslie, & Co., Hebburn-on-Tyne... ... ... (S) Dec. 1889
Matthews, A., Waterloo Road, Blyth... ... ... (S) Nov. 1884
Matthews, Jas., c/o Messrs. R. & W. Hawthorn, Leslie, & Co., Forth Banks, Newcastle-on-Tyne ... ... (E) Oct. 1886

ELECTED.

Mavor, Alfred E., Victoria Mansions, 32, Victoria Street, London, S.W. ... ... (E E) Feb. 1890
McBride, William, Warren Cement Works Cottages, Hartlepool... (E) Dec. 1894
McDougall, Neil, Managing Director, Messrs. British Steam Users' Insurance Society, Ld., 4 & 5, Victoria Buildings, Manchester (E) Mar. 1890
McGlashan, Arch., Beechcroft, Clifton Avenue, West Hartlepool (S) Nov. 1885
McIlvenna, J. G., c/o Messrs. The Tyne Pontoons and Dry Docks Co., Wallsend-on-Tyne ... ... (S) Nov. 1884
McKay, Jno., 19, Victoria Avenue, Whitley-by-the-Sea ... ... (E) Nov. 1884
McLaren, Robert M., Flinton Hill, Sunderland ... ... (S) Nov. 1893
McLaren, William, 8, London Grove, Prince's Road, Liverpool ... (E) Oct. 1894
Meldrum, Michael, 2, Belle Vue Crescent, Sunderland ... ... (E) Dec. 1893
Menzies, Wm., The Side, Newcastle-on-Tyne ... ... (E) Nov. 1884
Messenger, Thomas, Paris House, Snargate Street, Dover, Kent ... (E) Mar. 1887
Metcalf, J. C., 50, Frederick Street, Sunderland ... ... (SUR) Nov. 1884
Metcalf, Thos., Jun., 18, John Street, Sunderland ... (S) { Graduate, May 1885; Member, Nov. 1893 }
Metcalfe, C. S., 24, Croft Avenue, Sunderland ... ... (E) Nov. 1884
Micheli, Pietro, Jun., 20, Via Luccoli I°. P°., Genoa ... (E & N A) Oct. 1888
Middlemass, Thomas, 3, Albert Place, Norton Road, Stockton-on-Tees... ... ... (S) Oct. 1889
Middleton, H., Tyne View House, Whickham, Durhamshire (I & S M) Jan. 1893
Middleton, Robert Alexander, Fairfield Works, Govan, Glasgow... (N A) Oct. 1892
Milburn, Christopher J., 14, Falmouth Road, Heaton, Newcastle-on-Tyne ... ... (E) Feb. 1888
Millar. Thos., c/o Messrs. Sir W. G. Armstrong, Mitchell, & Co., Walker Shipyard, Walker-on-Tyne ... ... (S) Nov. 1884
Miller, Thomas B., 28, Mount Stuart Square, Cardiff (E) { Graduate, Nov. 1886; Member, Oct. 1888 }
Mills, John, c/o Messrs. Greenock Steam Shipping Co., Greenock ... ... (E) Feb. 1888
Mills, William. 16. St. George's Square, Sunderland ... ... (E) Feb. 1890
Milton, J. T., Lloyd's Register of Shipping, 2, White Lion Court, Cornhill, London, E.C. ... ... (E SUR) Nov. 1886
Mitchell, Chas., Jesmond Towers, Newcastle-on-Tyne ... ... (S) Nov. 1884
Moffatt, James, 7, Murray's Terrace, Belfast, Ireland (E) { Graduate, Dec. 1889; Member, Oct. 1892 }
Moffitt, George, 42, Stanley Street, Blyth ... ... (S) Oct. 1888
Moffitt, Robert, 13, Grace Terrace, Sunderland ... ... (E) Dec. 1885
Moody, Thomas V., Riding Mill, Northumberland ... ... (E) Dec. 1887
Moore, Frederick, c/o Messrs. Wilson, Sons, & Co., Ld., Pernambuco (E) Oct. 1890
Moorsom, Frederick, Queen Terrace, Seaton Carew ... ... (S) Nov. 1893
Morgan, W. H., 22, Rochdale Street, Wallsend-on-Tyne ... ... (E) Nov. 1884
Morison. D. B., 8, Albion Terrace, Hartlepool ... ... (E) Feb. 1885
Mörk, Peter, Lennox Hotel, Dumbarton, N.B. ... ... (E) Nov. 1884
Morrison, Robt., 5, Challoner Terrace, South Shields ... ... (E) Nov. 1886
Morrison, William. Lloyd's Register of Shipping, 2, White Lion Court, Cornhill, London, E.C. ... ... (E SUR) Oct. 1890
Morton, Richard Fraser, Lloyd's Register of Shipping, Newcastle-on-Tyne ... ... (E SUR) Oct. 1890
Mountain. William Chas., Messrs. Ernest Scott, Mountain, & Co., Close, Newcastle-on-Tyne ... ... (E Feb. 1889

ELECTED.

Mudd, Thomas, Central Marine Engine Works, West Hartlepool (E) Mar. 1886
Muir, Alfred Edward, 13, Joannah Street, Sunderland ... ... (S) Mar. 1893
Muir, Robert, 11, Clarence Crescent, Whitley, near Newcastle-on-Tyne ... ...(SUR) Oct. 1886
Muir, Robert Home, 1, Lovaine Crescent, Newcastle-on-Tyne ... (S) Oct. 1892
Myles, David, Northumberland Engine Works, Wallsend-on-Tyne (E) Nov. 1884

N.

Nastoupil, John, Chief Engineer, Austro-Hungarian Navy, Marine Casino, Pola, Austria ... ... (E) Nov. 1890
Nevins, William, c/o S. Todd, Esq., c/o Messrs. R. & W. Hawthorn, Leslie, & Co., Hebburn-on-Tyne ... ... (E) Mar. 1894
Newitt, Leonard, c/o Messrs. Sir W. G. Armstrong, Mitchell, & Co., Elswick Works, Newcastle-on-Tyne ... ... (E E) Dec. 1887
Newton, Richard, Park Square, West Hartlepool ... ... (E) April 1889
Newton, W. A., 29, Sea View Terrace, South Shields (E) {Graduate, May 1885 / Member, Oct. 1886}
Nicholls, H. E., 25, Churchill Street, Sunderland ... ... (E) Nov. 1893
Nichols, Walter W., 30, Denmark Street, Gateshead-on-Tyne ... (E) May 1895
Nicholson, John S., North View, Mowbray Road, Westoe, South Shields ... ... (E) Nov. 1893
Nicol, John M., 15, Linskill Terrace, North Shields ... ... (E) Nov. 1884
Nicolson, G. C., H.M.S. "Alexandra," Portland, Dorset (E) {Graduate, Oct. 1885 / Member, Oct. 1888}
Noble, George, 40, Westgate Road, Newcastle-on-Tyne ... ... (E) May 1893
Noble, Harry, Northern Machine Tool Works, Brewery Lane, Felling-on-Tyne ... ... (E) Nov. 1888
Nodder, Joseph, 503, Pitsmoor Road, Sheffield ... ... (F M) May 1893
Norman, W. S., Orchard House, Whitby, near Chester ... ... (E) Nov. 1884
Norton, Harold P., U.S.S. "Concord," Bureau Steam Engineering, Navy Department, Washington, U.S.A. ... ... (E) Oct. 1890
Noton, F. R., Lloyd's Register of Shipping, Ramsden Square, Barrow-in-Furness ... ... (S) Nov. 1884
Nunes, Enrique E., Engineer, Argentine Navy, 433, Calle Ayacucho, Buenos Ayres ... ... (E) April 1891

O.

O'Halloran, Timothy, 205, Avenue du Commerce, Antwerp, Belgium ... ... (E) Jan. 1895
Oliver, Hedley, 6, Tower Chambers, Water Street, Liverpool ... (E) Oct. 1892
O'Neil, J. J., 2, Erith Terrace, Sunderland ... ... (E) Nov. 1884
Orde, E. L., c/o Messrs. Sir W. G. Armstrong, Mitchell, & Co., Walker Shipyard, Newcastle-on-Tyne ... ... (E) Oct. 1887
Orlando, Chev. Giuseppe, Cantiere Navale, Fratelli Orlando, Leghorn ... ... (N A) Jan. 1893
Orr, Reginald, 18, Bulwer Street, Shepherd's Bush, London, W. ... ... (E) {Graduate, Mar. 1890 / Member, Oct. 1892}

ELECTED.

Oxley, G., 39, Norman Terrace, Howdon-on-Tyne ... ... (S) Nov. 1884

Oxton, Walter, 96, Blackpool Street, Burton-on-Trent (E) { Graduate, Dec. 1890 / Member, May 1894

P.

Pacey, John W., c/o Messrs. Midland Coal, Coke, & Iron Co., Apendale, near Newcastle, Staffordshire ... ... (E) Feb. 1888

Parsons, Hon. Charles A., Holeyn Hall, Wylam-on-Tyne ... ... (E E) Dec. 1887

Parsons, Harry F., 83, Cardigan Terrace, Heaton, Newcastle-on-Tyne ... ... (E) Dec. 1890

Pascoe, J. R., Tyrmont, Woodford, Essex (*Life Member*) ... ... (S) Dec. 1889

Patterson, Jas., West Lodge, Walker-on-Tyne ... ... (E) Nov. 1884

Pattison, Jos., 123, Bute Road, Cardiff ... ... (E) Nov. 1884

Paulson, John, Messrs. The Wm. Cramp & Sons' Ship and Engine Building Co., Philadelphia, U.S.A. ... ... (S) Feb. 1886

Peacock, Nicholas B. J., 30, Dingle Road, Tranmere Park, Birkenhead ... ... (E) Oct. 1892

Penney, R. H., Board of Trade Offices, 79, Mark Lane, London, E.C. ... ... (S SUR) Nov. 1884

Pepper, W., Sunnyside, West Villas, Oxbridge Lane, Stockton-on-Tees .. .. (E) Nov. 1888

Petersen, John L., 18, Bellerby Terrace, West Hartlepool... ... (E) Oct. 1888

Petree, James, Lloyd's Register of Shipping, 2, White Lion Court, Cornhill, London, E.C. ... ... (S) Oct. 1885

Petrini, Giacomo Luigi, C.E., c/o Messrs. Gio Ansaldo & Co., Sestri-Ponente, Italy ... ... (N A) Nov. 1892

Petterson, Carl Edwin, 7, Vestra Hamngaten, Gothenburg, Sweden (E) Oct. 1891

Philipson, Roland, Tynemouth... ... ... (E) Dec. 1884

Phillips, Walter, 28, Brownhill Road, Catford, London, S.E. (N A & E) Oct. 1886

Phorson, P., Glen Lea, Roker, Sunderland ... ... (S) Nov. 1884

Piaud, Leon, Bureau Veritas, 8, Place de la Bourse, Paris ... ... (N A) Nov. 1888

Pitt, Frederick William, 15, Wilberforce Terrace, Gateshead-on-Tyne... ... ... (E SUR) Oct. 1890

Plotnicki, E. C., The Avenue, Wallsend-on-Tyne ... ... (E) Nov. 1886

Poli, Rodolfo, Chioggia, Italy ... ... (N A) Jan. 1890

Potts, Matthew, 86. Glen Terrace, Hebburn-on-Tyne ... ... (S) Dec. 1890

Potts, Robert, 11, Mount Pleasant, Deptford, Sunderland... ... (S) Oct. 1888

Powell, James Richard, Pier Head Chambers, Cardiff ... ... (C E) May 1894

Price, F. D., 2, Bede Burn Street, Jarrow-on-Tyne... ... (E & S) Oct. 1888

Price, John, 6, Osborne Villas, Jesmond, Newcastle-on-Tyne ... (S) Nov. 1884

Prince, Alfred, Kent Villa, Jarrow-on-Tyne... ... ... (E) Nov. 1884

Pringle, Alfred, 10, Somerset Terrace, Walker-on-Tyne (S) { Graduate, Dec. 1891 / Member. Jan. 1894

Pringle, James G., 10, Somerset Terrace, Walker-on-Tyne... ... (S) Oct. 1892

Prosser, James, 205, Albert Road, Jarrow-on-Tyne... ... ... (E) Nov. 1893

Purdon, Andrew S., Fairfield Works, Govan, Glasgow ... ... (S) Oct. 1892

Purdy, A. J., Philipson Street, Willington Quay-on-Tyne ... (E) Nov. 1884

Purves, David, Wyborne Gate, Westcliffe Road, Birkdale, Southport ... ...(SUR) Dec. 1885

ELECTED.

Purvis, Fred. W., 5, Greatham Terrace, West Hartlepool ... ... (S) April 1893
Putnam, T., Darlington Forge, Darlington ... ... (F M) Nov. 1884
Putnam, William, Darlington Forge, Darlington ... ... (F M) Nov. 1884

Q.

Quicke, Herbert John, 5, Grazebrook Road, Clissold Park, London, N. ... ... (E) Feb. 1891

R.

Rae, John, 11, Gray Street, Glasgow, N.B. ... ... (E) April 1886
Ralston, G. C., The Grove, Walker Gate ... ... (E) Oct. 1887
Ramage, J. T., St. Aubyn's, Bonnington, Edinburgh ... ... (E) April 1887
Ramage, John Anderson, 74, Glen Terrace, Hebburn-on-Tyne ... (S) Oct. 1892
Readhead, Jas., Beach View, South Shields ... ... (S) Nov. 1884
Readhead, John, 4, Salisbury Place, South Shields.. ... ... (E) Mar. 1886
Readhead, R., 28, Sea View Terrace, South Shields ... ... (E) Nov. 1884
Readhead, W. B., South-garth, Westoe, South Shields ... ... (S) Nov. 1886
Reavell, W., c/o Messrs. Babcock & Wilcox, 147, Queen Victoria Street, London, E.C. ... ... (E) { Graduate, April 1885; Member, Oct. 1887
Reed, Joseph, Angerton House, North Shields ... ... (E) Oct. 1889
Reed, J. W., c/o Messrs. Palmer's Shipbuilding and Iron Co., Limited, Engine Works Department, Jarrow-on-Tyne ... (E) Nov. 1884
Reed, Richard, 36, Chillingham Road, Heaton, Newcastle-on-Tyne (S) Oct. 1894
Rennoldson, C., Messrs. J. P. Rennoldson & Sons, South Shields (S) Jan. 1886
Rennoldson, Jos. M., Messrs. J. P. Rennoldson & Sons, South Shields (S) Feb. 1886
Renton, John, 1, Akenside Hill, Newcastle-on-Tyne ... (M SUR) April 1895
Reynolds, Charles H., c/o Messrs. Sir W. G. Armstrong, Mitchell, & Co., Walker-on-Tyne ... ... (S) Mar. 1889
Reynolds, W. G., 36, Meldon Terrace, South Shields ... ... (E) Oct. 1886
Richardson, Philip Wigham, The Hawthorns, Half Moon Lane, Herne Hill, London, E.C. ... ... (S) Nov. 1890
Richardson, T., B.A., M.P., Hartlepool Engine Works, Hartlepool (E) April 1888
Richardson, Wigham, Neptune Works, Walker-on-Tyne ... ... (S) Nov. 1884
Rickaby, A. A., Bloomfield Engine Works, Sunderland ... ... (E) Mar. 1888
Ridley, J. H., Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's, Newcastle-on-Tyne ... ... (E) Nov. 1884
Riley, J. H., Messrs. Riley Bros., Stockton-on-Tees ... ... (B B) May 1893
Ritson, M., Lloyd's Register of Shipping, 29, Regent Quay, Aberdeen ... ... (E SUR) Nov. 1884
Ritson, S. M., 15, Ashmore Street, Sunderland ... (E) { Graduate, Nov. 1887; Member, Nov. 1893
Robinson, B. A., 12, Harold Street, Sunderland ... ... (E) Nov. 1884
Robinson, William, 7, Choppington Street, Newcastle-on-Tyne ... ... (E) { Graduate, May 1885; Member, April 1888
Robson, Arthur, Messrs. J. Blumer & Co., North Dock, Sunderland (S) Dec. 1886
Robson, George, 9, Wellington Terrace, South Shields ... ... (E) Oct. 1889
Robson, Geo. Edward, 61, Thornton Street, West Hartlepool ... (S) Nov. 1893
Robson, John H., Grainger Commercial Hotel, Newcastle-on-Tyne (E) Nov. 1885
Robson, J. M., 4, Abbey Terrace, Gateshead-on-Tyne ... ... (E) Nov. 1884

ELE

Sharp, A. E., 16, Bede Burn Road, Jarrow-on-Tyne ... ... (E) Nov.
Sharp, Mark, 144, Albert Road, Jarrow-on-Tyne ... ... (E) Dec.
Shaw, Jas., 26, Sandhill, Newcastle-on-Tyne ... ... (M SUR) Jan.
Sheriff, Thomas, c/o Messrs. Robert Mackill & Co., 29, Waterloo Street, Glasgow ... ... (E) April
Shevill, W. H., 5, Avenue Terrace, Sunderland ... ... (E) Nov.
Short, J. Y., 49, West Sunniside, Sunderland ... ... (S) Nov.
Short, Jos., 49, West Sunniside, Sunderland... ... ... (S) Nov.
Shotton, John W., 32, Mount Stuart Square, Cardiff ... ... (SUR) Nov.
Shute, A. E., 12, Clyde View, Partick, Glasgow ... ... (E) Dec.
Simpson, Edward, Buddle Street, Wallsend-on-Tyne ... ... (S) Dec.
Sinclair, R., c/o Messrs. J. Wildridge & Sinclair, Consulting Engineers, 97, Pitt Street, Sydney, N.S.W., Australia ... (C E) Nov.
Sinton, John K., 26, Sandhill, Newcastle-on-Tyne... ... ... (E) Nov.
Sisson, Wm., Gloucester ... ... (E & N A) Oct.
Sisterson, G. R., Locomotive Department, London and South Western Railway, Nine Elms, London, S.W.... ... ... (E) Nov.
Sivewright, G. W., 5, Radcliffe Terrace, Hartlepool ... ... (S) Nov.
Skinner, Leslie, Ravensbourne Terrace, South Shields (S) { Graduate, Dec. / Member, Oct.
Smith, C. E., 73, Thornton Street, West Hartlepool ... ... (E) Nov.
Smith, Eustace, 5, Queen Street, Newcastle-on-Tyne ... ... (S) Nov.
Smith, John Law, West Hartlepool Steel and Iron Works, West Hartlepool ... ... (I & S M) May
Smith, L. Eustace, 22, St. Mary's Place, Newcastle-on-Tyne... ... ... (E) { Graduate, Oct. / Member, Oct.
Smith, Malden H., c/o Col. F. J. Smith, R.E., Belmont, Ryde, Isle of Wight ... ... (S) April
Smith, R. J., Pier Engine Works, South Dock, Sunderland ... (E) Nov.
Smith, Thomas, Steam Crane Works, Old Foundry, Rodley, near Leeds (E) Oct.
Smith, Thomas Edward, Messrs. John Smith & Sons, Newgate Street, Newcastle-on-Tyne ... ... (E) April
Smith, Wm., 51, Dock Street East, Sunderland ... ... (E) Nov.
Soliani, Nabor, Sotto Direzione Delle Costruzioni Navali del Rº Cantiere di Castellammare di Stabi, Italy ... ... (S) Jan.
Sowter, Isaac G., Messrs. The Cleveland Shipbuilding Co., Cleveland, Ohio, U.S. America ... ... (E) Jan.
Spear, John, c/o Messrs. T. Wilson & Sons, Hull ... ... (E) Oct.
Spearman, Richard, Eachwick House, Dalton, Newcastle-on-Tyne (E) Feb.
Spence, W. G., c/o George Clark, Esq., Southwick Engine Works, Sunderland (*Life Member*) ... ... (E) Nov.
Spencer, J. W., Newburn Steel Works, Newburn-on-Tyne ... (E) Feb.
Stafford, William, Dunston-on-Tyne ... ... (E) Nov.
Stansfield, George R., The Grove, Westoe, South Shields... ... (E) Mar.
Stephenson, C., 2, Elm Terrace, The Green, Wallsend-on-Tyne ... (S) Nov.
Stevenson, Wm., 6, West View, Wallsend-on-Tyne ... ... (E) Nov.
Stewart, James, 31, Lily Avenue, Jesmond, Newcastle-on-Tyne .. (E) Oct.
Stirling, Andrew, Jun., 1, Greenvale Terrace, Dumbarton... ... (E) Feb.
Stirzaker, J. C., 16, Grosvenor Place, Newcastle-on-Tyne... ... (E) Nov.
Stoddart, J. E., Lloyd's Register of Shipping, 3, St. Nicholas' Buildings, Newcastle-on-Tyne ... ... (E SUR) Oct.

ELECTED.

Stoddart, Swinton, 24, North Milburn Street, Sunderland (S) { Graduate, May 1885 / Member, Nov. 1892

Stokoe, Thomas W., 32, Scarboro' Street, West Hartlepool ... (S) Dec. 1885

Stone, Wm., 13, Rosslyn Terrace, Sunderland ... ... Nov. 1884

Strong, George Aaron, 87, West Percy Street, North Shields ... (E) Dec 1889

Stroughair, John W. H., Whitewell Lane, Ryton-on-Tyne ... (E) Nov. 1894

Summers, James, 114, Grange Road West, Middlesbrough ... (E) Mar. 1889

Summersby, Robert Arthur, 4, Otterburn Terrace, Jesmond, Newcastle-on-Tyne ... ... (E) Oct. 1891

Surtees, Francis V., Westbourne Street, Stockton-on-Tees ... (S) Dec. 1892

Surtees, R., Frame House, Low Teams, Gateshead-on-Tyne ... (E) Nov. 1884

Swan, A. S., Grove House, Gosforth, Newcastle-on-Tyne ... ... (S) Nov. 1888

Swan, Charles Sheriton, c/o Messrs. C. S. Swan & Hunter, Wallsend-on-Tyne... ... ... (S) { Graduate, Nov. 1890 / Member, Mar. 1894

Swan, H. F., North Jesmond, Newcastle-on-Tyne ... . (S) Nov. 1884

Swinburne, M. W., 117, Park Road, Newcastle-on-Tyne ... ... (E) Nov. 1884

Swinburne, T. M., Bewick Road, Gateshead-on-Tyne ... ... (E) Jan. 1885

Swinney, W., 10, Wentworth Terrace, Westoe Lane, South Shields (E) Dec. 1888

Sydserff, Thomas B., Jun., 68, Bath Road, Totterdown, Bristol ... (E) Oct. 1888

Syme, James, Fairfield Works, Govan, Glasgow ... ... (E) Oct. 1892

T.

Tate, Chas. H., 7, Side, Newcastle-on-Tyne ... ... (N A) Nov. 1884

Taylor, Alexander, Maritime Buildings, King Street, Newcastle-on-Tyne ... ... (E) Nov. 1884

Taylor, C. W., South Garth, Westoe, South Shields ... ... (E) April 1885

Taylor, John, 53, Heaton Park Road, Heaton, Newcastle-on-Tyne (E) Dec. 1894

Thompson, C. E., Messrs. J. L. Thompson & Sons, North Sands, Sunderland... ... ... (S) Nov. 1884

Thompson, Charles, M.A., 33, Mosley Street, Newcastle-on-Tyne (E) Feb. 1887

Thompson, Jas., 11, Elmwood Street, Sunderland ... ... (E) Dec. 1886

Thompson, John Augustus, 12, London Street, Fenchurch Street, London, E.C. ... ... (E & N A) Oct. 1892

Thompson, J. L., North Sands Shipyard, Sunderland ... ... (S) Nov. 1884

Thompson, Robert, North Sands Shipyard, Sunderland ... ... (S) Nov. 1884

Thomson, James, M.A., c/o Messrs. Sir W. G. Armstrong, Mitchell, & Co., Ordnance Works, Elswick, Newcastle-on-Tyne (E & N A) Nov. 1890

Thorn, W. H., 5, Waterville Terrace, North Shields ... ... (E) Nov. 1884

Thornton, James, c/o Messrs. The Mercantile Dry Dock Co., Ltd., Jarrow-on-Tyne ... ... (E) April 1893

Tinn, Fred. D., 2, Sunningdale Terrace, South Shields ... ... (E) Nov. 1891

Tinwell, George, General Gordon Terrace, Sunderland ... ... (E) Jan. 1889

Todd, Surtees, c/o Messrs. R. & W. Hawthorn, Leslie, & Co., Hebburn-on-Tyne ... ... (S) Nov. 1884

Todd, Thomas, 19, Billiter Street, London, E.C. ... ... (E) Nov. 1885

Toovey, Alfred F., Ovington Cottage, Prudhoe, Northumberland (E) Dec. 1894

Topham, Henry George, 13, Choppington Street, Newcastle-on-Tyne... ... ... (E) May 1891

Topp, Carl, Schichan Werfl, Danzig, Germany ... ... (S) Oct. 1894

ELECTED.

Towers, Edward, Jun., 4, Latimer Street, Tynemouth (E) {Graduate, Nov. 1886 / Member, Oct. 1888}

Trail, John, 25, Sanderson Road, Jesmond, Newcastle-on-Tyne (M S) Oct. 1892

Trewent, F. J., 43, Billiter Buildings, Billiter Street, London, E.C. ... ... (S) Dec. 1884

Trowell, Wm. John, 37, Caroline Street, Jarrow-on-Tyne ... (E) Oct. 1894

Tulip, George, Universities Mission, Lake Nyassa, Central Africa (E) Dec. 1888

Turnbull, Charles, Jun., Hilton Lodge, North Shields ... ... (E E) Oct. 1894

Turner, S. J., 71, Warwick Street, Heaton, Newcastle-on-Tyne ... (E) Mar. 1887

Twaddell, James L., 4, St. John's Terrace, Jarrow-on-Tyne ... (S) Oct. 1891

Tweddell, R. H., Meopham Court, Gravesend, London ... ... (E) Jan. 1885

Tweedy, J., Neptune Works, Walker-on-Tyne ... ... (E) Nov. 1884

Twigden, George J., c/o Messrs. Hick Bros., Mount Stuart Square, Cardiff ... ... (E) Jan. 1890

Tyzack, George, Dean Street, South Shields... ... ... (E) April 1888

U.

Ullstrom, Otto, 84, Leadenhall Street, London, E.C. ... ... (S) Nov. 1884

Ulm, John, The Arsenal, Pola, Austria ... ... (E) Nov. 1885

V.

Vianson, N. E., *viâ* Galeazzo Alessi 6 into 1, Genoa, Italy... ... (E) Dec. 1885

Vick, R. W., Messrs. Furness, Withy & Co., Middleton Shipyard, West Hartlepool ... ... (S) Nov. 1888

Vivet, Leon, 12, Rue de Seine, Paris ... ... (N A) Nov. 1892

W.

Wadagaki, Yasuzo, Imperial Naval Dockyard, Yokosuka, Japan ... (E) Jan. 1891

Wailes, E. F., 4, St. Nicholas' Buildings, Newcastle-on-Tyne ... (N A) Nov. 1884

Wailes, T. W., Mount Stuart Dry Docks, Cardiff ... ... (E & S) Oct. 1887

Wait, Thomas Herbert, Cail's Buildings, Quayside, Newcastle-on-Tyne... ... ...(C E) Dec. 1893

Wake, Tom, Church Walk, Hartlepool ... ... (E) April 1892

Walker, Archibald, Elizafield House, North Fort Street, Leith, N.B. (E) April 1887

Walker, Henry, 11, Oxford Terrace, Gateshead-on-Tyne ... ... (E E) Feb. 1893

Walker, John, c/o Messrs. R. Stephenson & Co., Limited, South Street, Newcastle-on-Tyne ... ... (E & S) Nov. 1891

Wallau, J., c/o Messrs. Black, Hawthorn, & Co., Gateshead-on-Tyne (E) Nov. 1884

Walliker, J. F., Lloyd's Register of Shipping, Bute Docks, Cardiff (E) Nov. 1885

Wallis, Robert, Point Pleasant House, Wallsend-on-Tyne... ... (E) April 1891

Walter, Max, 120B, Smidtstr, Bremerhaven ... ... (S) Feb. 1893

Walton, J. G., 26, Fenchurch Street, London, E.C. ... ... (E) Nov. 1884

Walton, Samuel, 34, Pollard Street, South Shields ... ... (E) Dec. 1893

Warburton, J., 19, Lorne Terrace, Sunderland ... ... (E) Nov. 1884

Ward, John, c/o Messrs. W. Denny & Bros., Dumbarton ... ... (S) Dec. 1891

ELECTED.

Y.

Yale, Thomas P. O., 11, Warrington Road, Westmorland Road, Newcastle-on-Tyne ... ... (E) Dec. 1894
Young, Andrew, Bureau Veritas, 155, Fenchurch Street, London, E.C. ... ... (S) Graduate, Feb. 1892; Member, May 1893
Young, J. Denholm, West India House, 96, Leadenhall Street, London, E.C. ... ... (E) Oct. 1888
Younger, R., Elmire House, Heaton, Newcastle-on-Tyne ... ... (E) Nov. 1884

Z.

Zeeman, J. H., c/o Messrs. The Maas Co., Rotterdam ... ... (S) Oct. 1889

ASSOCIATES.

A.

Adam, John B., 8, Osborne Terrace, Newcastle-on-Tyne ... ... (O) Nov. 1893
Anderson, Daniel G., Burnaby Lodge, Ryton-on-Tyne ... ... (A) Nov. 1893
Armstrong, S., 14, Victoria Place, Hartlepool ... ... (A) Nov. 1888

B.

Bacon, William Charles, Chadwick House, West Hartlepool ... (S O) Dec. 1890
Ball, Alfred F., 14, Landsdowne Terrace, Gosforth, Newcastle-on-Tyne... ... ... (A) Nov. 1894
Barklam, George, 167, Dudley Port, Tipton, Staffordshire ... (A) April 1888
Barr, John Smith, 5, Mosley Street, Newcastle-on-Tyne ... ... (A) Nov. 1893
Barraclough, Thomas, Messrs. The West Hartlepool Steam Navigation Co., West Hartlepool ... ... (S O) Dec. 1890
Barwick, J. S., Ashbrook Grange, Sunderland ... ... (S O) Nov. 1884
Bell, John Henry, 39, Albert Drive, Pollockshields, Glasgow (I & S M) Oct. 1887
Beynon, Thomas, 9, Dean Street, Newcastle-on-Tyne ... ... (E A) Oct. 1891
Bigge, C. W., Northern Counties Club, Newcastle-on-Tyne ... (A) Dec. 1889
Bingham, Col. J. E., Manufacturer, West Lea, Sheffield ... ... Mar. 1895
Blacklin, Richard James, Dinsdale House, Brougham Terrace, West Hartlepool ... ... (S O) Dec. 1890
Branfoot, W. J., Messrs. Tyzack & Branfoot, 18, John Street, Sunderland ... ... (S O) Dec. 1887
Briggs, R. S., Moorlands, Sunderland ... ... (S O) Dec. 1886
Brims, D. N., 4, St. Nicholas' Buildings, Newcastle-on-Tyne ... (C) Nov. 1893
Brunton, John, 3, Prior's Terrace, Tynemouth ... ... (S O) Oct. 1886
Bullen, Tempest C., c/o Messrs. H. E. Moss & Co., K. Exchange Buildings, Newcastle-on-Tyne ... ... (S O) Nov. 1891

C.

Carnegy, Robert B., Kimberley Club, Kimberley, South Africa ... (A) Oct. 1891
Carr, Ralph, Thornleigh, Clayton Road, Newcastle-on-Tyne (A & S O) Nov. 1886
Cassap, William, 15, East Field Road, Walthamstow, Essex ... (SUR) Feb. 1890
Caws, Frank, 22, Fawcett Street, Sunderland ... ... (C E) Oct. 1892

		ELECTED.
Cohan, Edward Asher, 2, Rumford Place, Liverpool	(S O)	Nov. 1889
Common, Francis James, 5, Elms West, Sunderland ...	(I & S M)	Oct. 1887
Conner, L. R., Exchange, West Hartlepool	(S O)	Jan. 1891
Cooper, Charles, Average Adjuster, Wellington Road, West Hartlepool	(A A)	April 1893
Corbitt, Michael, 13, Mosley Street, Newcastle-on-Tyne	(R M)	Jan. 1890
Coull, John, 43, Stanley Street West, North Shields	(S O)	Oct. 1886
Coverdale, R. H., Messrs. J. Coverdale & Sons, Steamship Owners, West Hartlepool	(S O)	Nov. 1888
Crosier, Edward James, 3, The Hawthorns, East Boldon	(A)	Oct. 1889
Culliford, J. H. W., 45, West Sunniside, Sunderland	(S O)	Nov. 1884

D.

Dodds, A. P., 13, Dean Street, Newcastle-on-Tyne	(A)	Jan. 1889
Dodds, E. F., 36, Side, Newcastle-on-Tyne	(A)	Nov. 1893
Dodds, John B., 36, Side, Newcastle-on-Tyne	(CHEM)	Oct. 1888
Dove, Edward John, 5, St. Nicholas' Buildings, Newcastle-on-Tyne		Oct. 1890

E.

Eccles, Edward, Royal Insurance Buildings, Queen Street, Newcastle-on-Tyne (*Life Associate*)...	(S O)	Oct. 1887

F.

Furness, Sir Christopher, Baltic Chambers, West Hartlepool ...	(S O)	Oct. 1888

G.

Garnett, William, LL.D., 13, Spring Gardens, London, S.W. ...		Jan. 1889
Graham, Frank, Bank Chambers, Mosley Street, Newcastle-on-Tyne	(E A)	Nov. 1891

H.

Hardy, John, Jun., Brunswick Street, West Hartlepool	(I M)	Nov. 1893
Harland, George, 1, Westoe Crescent, South Shields	(A)	Dec. 1888
Harrison, Thomas, 9, Bridge Street, Sunderland	(A)	Dec. 1894
Hedley, John H., 10, Esplanade West, Sunderland	(S)	Dec. 1886
Henzell, Robert, Northern Oil Works, Close, Newcastle-on-Tyne (*Life Associate*)	(A)	Nov. 1893
Heslop, Richard O., Akenside Hill, Newcastle-on-Tyne ...	(I & S M)	Oct. 1885
Hollis, H. E., 23, Lilybank Gardens, Hillhead, Glasgow ...	(I & S M)	Feb. 1885
Hudson, Ralph M., Jun., 8, The Cedars. Sunderland	(S O)	Dec. 1886
Hunting, Charles, 1, Exchange Buildings, Quayside, Newcastle-on-Tyne	(S O)	April 1886
Hurndall, Sidney E., Printing Court Chambers, Newcastle-on-Tyne	(A)	Nov. 1893

ELECTED

I.

Innes, Charles H., Rutherford College, Newcastle-on-Tyne ... (E) Oct. 1891

J.

Jenkins, Alfred, Tweed House, Victoria Terrace, Jarrow-on-Tyne (A) Nov. 1893
Jobson, W. J., c/o Messrs. Robert Stephenson & Co, South Street, Newcastle-on-Tyne ... ... (A) May 1889
Jordan, John George, 24, Stansfield Street, Sunderland ... ... (A) Nov. 1892

L.

Lennard, William, c/o Messrs. J. M. Lennard & Sons, Middlesbrough ... ... (S) Dec. 1891
Lloyd, John, Deptford Shipyard, Sunderland .. .. (A) Oct. 1894
Lockie, John, 4, Sanderson Road, West Jesmond, Newcastle-on-Tyne... ... ... (S O) Oct. 1892
Loveridge, W. H., Albert Terrace, West Hartlepool ... (I & S M) Oct. 1888

M.

Macarthy, George E., 9, Dean Street, Newcastle-on-Tyne... ...(S O) Oct. 1887
Mail, Douglas B., 14, Humbleton View, Sunderland ... ...(M S) Feb. 1895
Maughan, Thos., Jun., Hollyfield House, Sorley Street, Sunderland (A) Nov. 1893
Maughan, William, 13, Mosley Street, Newcastle-on-Tyne ... (A) Feb. 1887
McIntosh, R. Y., 53, Quayside, Newcastle-on-Tyne ... ... (E A) Nov. 1891
McIntyre, John, 3, Abbotsford Terrace, Newcastle-on-Tyne ... (S O) Jan. 1885
McNabb, Thos., Cail's Buildings, Quayside, Newcastle-on-Tyne ... (S O) Nov. 1886
Meek, John George, 10, Belle Vue Road, Tunstall Road, Sunderland ... ... (A) Dec. 1894
Metcalf, Thomas, 18, John Street, Sunderland ... ...(SUR) Jan. 1888
Milburn, J. D., Queen Street, Newcastle-on-Tyne ... ... (S O) Nov. 1884
Miller, T. R., 9, Great St. Helen's, London, E.C. ... ... (A & S O) Nov. 1884
Mitcalfe, John Stanley, Chairman of Northern Maritime Insurance Co., Maritime Buildings, Newcastle-on-Tyne ... ... (A & S O) Jan. 1892
Muir, James, 2, Dingle Lane, Liverpool ... ... (M S) Nov. 1893
Mulherion, G. F., Croft Villa, Jarrow-on-Tyne ... ... (A) Nov. 1884
Muller, J. C. F., 28, Vieille Route, Antwerp ... ...(SUR) Feb. 1890
Murray, Matthew, The Green, Wallsend-on-Tyne ... ... (A) Nov. 1893

N.

Newby, S., c/o Messrs. Thomson & Newby, Edinburgh Chambers, 41, Fawcett Street, Sunderland... ... ... (I & S M)Nov. 1884
Nicholson, John, 7, Side, Newcastle-on-Tyne ... ... (M S) Nov. 1890
Nixon, John, c/o Messrs. Blyth Shipbuilding Co., Blyth ... ... (A) Oct. 1894

O.

O'Hagan, James, 99, Quai de la Fosse, Nantes, France ... ... (A) Oct. 1888
Olsen, Hans Benedick, 70, Church Street, West Hartlepool ... (S O) Mar. 1893
Osbourne, Jas., 11, The Oaks, Sunderland ... ... (S) Jan. 1885

ELECTED.

P.

Patterson, Thos., 2, The Elms, Sunderland ... ... (S) Jan. 1885
Perry, Edwin, Queen Street, Newcastle-on-Tyne ... ... (A) Nov. 1885
Petersen, William, 7, Haldane Terrace, Jesmond, Newcastle-on-Tyne... ... ... (S O) Nov. 1893
Phalp, Oliver, Almora, 37, Richmond Road, Cardiff ... ...(SUR) Feb. 1889
Pinkney, Thomas, 3, Ashbrook Terrace, Sunderland ... ...(S O) Dec. 1886
Pirrie, Robert Reid, Baltic Chambers, Quayside, Newcastle-on-Tyne (S O) Dec. 1889
Proctor, J. H., 22, Hawthorn Terrace, Newcastle-on-Tyne ... (I M) Nov. 1893

R.

Radloff, Captain O., Marine Superintendent, Russian Volunteer Fleet Committee, 14, Catherine Canal, St. Petersburg, Russia ... ... (M S) Nov. 1891
Ramsay, J. W., 13, Northbrook Road, Lee, Kent ... ... (A) Feb. 1885
Reichwald, A., Lombard Street, Newcastle-on-Tyne ... ... (A) Nov. 1884
Reid, Andrew, Printer, Akenside Hill, Newcastle-on-Tyne ... Nov. 1884
Renwick, G., Messrs. Fisher, Renwick, & Co., Queen Street, Newcastle-on-Tyne ... ... (S O) Nov. 1884
Rickinson, John, 9, Church Street, West Hartlepool ... ... (S O) Nov. 1890
Robson, Frederick, 46, Dean Street, Newcastle-on-Tyne ... (S I M) Oct. 1887
Robson, Thos., Causeway House, Sunderland ... ...(S O) Nov. 1884
Runcieman, John Finley, 38, Larkspur Terrace, Jesmond, Newcastle-on-Tyne ... . (M S) Nov. 1892
Runciman, Walter, Fernwood House, Clayton Road, Newcastle-on-Tyne ... ... (S O) May 1895

S.

Scholefield, A., 17, Sandhill, Newcastle-on-Tyne ... ... (S O) Nov. 1884
Scott, W. H., Messrs. Scott Brothers, Dean St., Newcastle-on-Tyne (S O) Nov. 1884
Sinclair, John, Church Street, West Hartlepool ... ... (S O) Feb. 1895
Snowdon, W. F., 32, Side, Newcastle-on-Tyne ... ... (E A) Dec. 1886
Squance, J. W., 13, The Avenue, Sunderland ... ... (M S) April 1888
Swan, Isaac J., Grove House, Gosforth, Newcastle-on-Tyne ... (S O) Feb. 1888

T.

Tate, Arthur, Bank Chambers, Sandhill, Newcastle-on-Tyne ... (O) Nov. 1893
Thompson, V. T., Baltic Chambers, Sunderland ... ...(S O) Dec. 1886
Towers, Edward, 4, Latimer Street, Tynemouth ... ... (A) Oct. 1888

W.

Wade, Wentworth S., 2, Otteran Place, South Parade, Waterford (M S) April 1895
Wait, James, Maritime Buildings, King Street, Newcastle-on-Tyne (S O) Nov. 1884
Wait, John, 12, Broughton Road, South Shields ... ... (A) Oct. 1891
Walker, James, c/o Messrs. Gilchrist, Walker, & Co., Constantinople (S O) Mar. 1894

ELE

Wallace, Wm., 27, South Scarborough Street, West Hartlepool ... (A) Oct.
Watson, Thomas W., Gisburn House, Hartlepool ... ... (M S) Nov.
Weatheral, Henry, 27, Alderson Street, West Hartlepool ... (A) Feb.
Wilson, F. Alfred, 45, West Sunniside, Sunderland ... ... (I M) Nov.

Y.

Yeoman, F., Messrs. Murrell & Yeoman, West Hartlepool ... (S O) Nov.
Younger, Robert Laurie, Messrs. Greenock Steamship Co., Limited, Greenock ... ... (A) Feb.

GRADUATES.

A.

Adams, Cecil Turner, 1, Race Street, Newcastle-on-Tyne ... ... (E) Oct.
Adams, Dawson, Brinkburn Terrace, Westoe, South Shields ... (E E) Oct.
Anderson, John, University College, Gower Street, London, W.C. (E) Oct.
Andrew, David, Jun., 33, Osborne Road, Newcastle-on-Tyne ... (E) Oct.
Ashton, Arthur W., 29, Falconar Street, Shieldfield, Newcastle-on-Tyne... ... ... (E) Dec.

B.

Baker, Ernest T. ... ... (E) Nov.
Barbour, John, 1, Logan Terrace, South Shields ... ... (E) Nov.
Beale, Harry, Otterburn Terrace, Newcastle-on-Tyne ... ... (S) Jan.
Beilby, Norman Harry, 1, Kingsley Place, Heaton, Newcastle-on-Tyne ... ... (E) Dec.
Bennet, Arnold, 47, Grove Street, Elswick Road, Newcastle-on-Tyne... ... ... (N A) Dec.
Bent, John Bradbury, 17, Denmark Street, Gateshead-on-Tyne ... (E E) May
Bentham, Frederick Lister, 9, Bellegrove Terrace, Newcastle-on-Tyne... ... ... (E) Dec.
Bilbrough, Kenneth L., Thornby, Strawberry Hill, Middlesex ... (E) Nov.
Binns, Aubrey B., 23, Thornhill Terrace, Sunderland ... ... (E) Oct.
Borthwick, Robert J., 8, Kensington Terrace, Newcastle-on-Tyne (E) Dec.
Boswell, Cecil Robert, The Hollies, North Walsham, Norfolk ... (E) Nov.
Bowden, John, Sheriff Mount, Gateshead-on-Tyne ... ... (E) Jan.
Brodin, Olof, Gefle, Sweden ... ... (S) Mar.
Brown, George M., 243, Albert Road, Jarrow-on-Tyne ... ... (E) April
Bryers, Charles, 10, The Avenue, Sunderland ... ... (E) Dec.
Bulmer, Frederick Charles, 1, Graingerville North, Newcastle-on-Tyne... ... ... (E) May
Bulmer, Septimus, 1, Graingerville North, Newcastle-on-Tyne ... (E) May
Burn, Donald B., 7, The Elms West, Sunderland ... ... (S) Nov.
Burnett, Jacob Edward, 10, Prior's Terrace, Tynemouth ... ... (E) Oct.

ELECTED.

C.

Cadman, C. C., Clifton Holme, York ... ... (E) Nov. 1891
Cairns, Charles W., 84, Addison Road, Heaton, Newcastle-on-Tyne (E) Nov. 1894
Calvert, T. Horsfall, 4, South Crescent, Hartlepool ... ... (E) Nov. 1891
Carpmael, Richard Herbert, Boscobel, Crown Lane, Streatham Common ... ... (E) Jan. 1893
Carr, Ralph, Jun., Thornleigh, Clayton Road, Newcastle-on-Tyne (E) Jan. 1894
Carter, Thomas, Jun., Belle Vue Park, Sunderland ... ... (E) Nov. 1891
Coatsworth, George S., 1, Humbleton View, Sunderland ... ... (E) Nov. 1891
Coull, Alex. B., 43, Stanley Street W., North Shields ... ... (E) Feb. 1887
Cowell, Richard E., Montpellier, Sunderland ... ... (E) Dec. 1893
Crawford, J. F., c/o John Dickinson, Esq., Palmer's Hill Engine Works, Sunderland ... ... (E) Nov. 1893
Crawhall, Henry F., 2, Gloucester Terrace, Newcastle-on-Tyne (E E) May 1894
Crombie, W. Alan D., 13, Eldon Street, Newcastle-on-Tyne ... (E E) Oct. 1894

D.

Davis, James Albert, 4, Dickinson Crescent, Gosforth, Newcastle-on-Tyne ... ... (S) Dec. 1892
Davison, William H. G., 49, Sanderson Road, West Jesmond, Newcastle-on-Tyne ... ... (E) Dec. 1892
Dobson, Henry James, c/o Messrs. William Dobson & Co., Walker-on-Tyne, R.S.O. ... ... (S) Oct. 1891
Donovan, John, 5, Ash Place, Sunderland ... ... (E) Dec. 1892
Duckitt, J. Brentnall, c/o Messrs. Joseph Adamson & Co., Hyde, Cheshire ... ... (E E) Oct. 1888
Duckitt, Talbot, Leazes Gate Villa, Spital Tongues, Newcastle-on-Tyne ... ... (E E) Oct. 1891

E.

Edminson, Frank A., Otterburn Villas, Newcastle-on-Tyne ... (S) Nov. 1893

F.

Featherstonhaugh, Albany, 13, Park Place West, Sunderland ... (E) Oct. 1894
Ford, Hugh M., Assistant Engineer, R.N., H.M.S. "Ramillies," Mediterranean Squadron ... ... (E) Nov. 1893
Forster, Alfred L., 2, Shaftesbury Place, Gateshead-on-Tyne ... (E) Nov. 1891
Forster, Edgar S., 2, Shaftesbury Terrace, Gateshead-on-Tyne ... (E) Jan. 1894
Forster, L. P., 23, Lovaine Crescent, Newcastle-on-Tyne ... ... (E) Nov. 1893

G.

Gibson, Thomas, 162, Roker Avenue, Monkwearmouth, Sunderland (E) Nov. 1893
Golledge, W. ... ... (E) Nov. 1891

ELECTED.

H.

Hamilton, Robert C., The College, Durham ... ... (E) Dec. 1892
Hancock, Bede, St. Bede's Vicarage, Sunderland, M. ... ... (E) Dec. 1894
Hewitt, John, 29, Holly Street, Jarrow-on-Tyne ... ... (S) Nov. 1890
Hick, Charles, 21, Sea View Terrace, South Shields ... ... (E) Oct. 1894
Hinchliffe, Robert, 25, Hawthorn Street, Newcastle-on-Tyne ... (S) Nov. 1893
Hudson, Charles J., 84, Addison Road, Heaton, Newcastle-on-Tyne... ... ... (E) Nov. 1894
Hughes, Thomas C., 3, Summerhill Street, Newcastle-on-Tyne ... (E) Nov. 1893

J.

Jepson, Henry, 34, St. Mary's Place, Newcastle-on-Tyne ... ... (E) Nov. 1893
Johnson, Alington, 22, Camden Street, Southwick, Sunderland ... (E) Mar. 1892
Jonas, Owen M., 23, Lovaine Crescent, Newcastle-on-Tyne .. (E E) Dec. 1894

K.

Keen, Harry Bernard, 6, Beauclere Terrace, Sunderland ... ... (S) Dec. 1889
Kennedy, Robert Sinclair, 19, James Terrace, Wallsend-on-Tyne (E) April 1893
Kerr, William, c/o Messrs. J. & G. Thompson & Co., Clydebank, Glasgow ... ... (S) Oct. 1891
Kitchin, Arnold, Marine Parade, East Hartlepool ... ... (E) Dec. 1892

L.

Laing, Hugh, Thornhill, Sunderland ... ...(N A) Dec. 1894
Lishman, John James, Jun., 16, Lovaine Place, North Shields ... (E) Dec. 1892
Lynn, John Robert Dent, 31, General Gordon Terrace, Sunderland (E) April 1893

M.

Macdonald, William C., 15, Union Street, Hartlepool ... ... (E) Mar. 1895
Mace, Charles, 253, Albert Road, Jarrow-on-Tyne ... ... (E) Nov. 1894
Maslen, Frank E., 14, Belsize Park Gardens, Hampstead, London, N.W. ... ... (E) Nov. 1891
Mather, Clifford B. ... ... (S) Oct. 1892
McKenna, Francis, 46, Hodgson Street, Willington Quay-on-Tyne (E) Dec. 1890
McRobie, Frank, 25, Victoria Street, Newcastle-on-Tyne ... ... (E) Mar. 1889
Mellanby, Alexander L., Fern Leigh, Grange Road, West Hartlepool ... ... (E) Dec. 1894
Moroney, Edward F., 46, Third Avenue, Heaton, Newcastle-on-Tyne (E) Feb. 1892
Mould, Francis, 36, Salter's Road, Gosforth, Newcastle-on-Tyne... (E) Feb. 1892
Murray, George Harper, Blythwood Place, Inchinnan Road, Renfrew ... ... (S) Dec. 1892
Musgrave, Evers, 147, St. Owen's Street, Hereford ... ... (E) Nov. 1891

N.

Nichol, Bryce Gray, 35, Leazes Terrace, Newcastle-on-Tyne ... (E) Oct. 1891
Nicholson, James Henry, 30, Azalea Terrace South, Sunderland ... (E) Mar. 1892

ELECTED.

O.

Olsen, Hans B., Jun., Wellington Road, West Hartlepool... ... (E) Feb. 1895

P.

Palmer, Henry G., 12, Havelock Street, Newcastle-on-Tyne ... (E E) Dec. 1894
Patterson, Robt. O., Thorneyholme, Blaydon-on-Tyne ... ... (E) Jan. 1895
Pearce, Standen L., 42, York Road, West Hartlepool ... ... (E) Dec. 1893
Pearson, James, 10, Beech Grove Road, Newcastle-on-Tyne ... (S) Nov. 1893
Pendred, L. St. L., 186, Portland Road, Newcastle-on-Tyne ... (E) Mar. 1894
Pettit, Arthur Edward, Oatlands Park, Weybridge ... ... (E) Dec. 1892
Phillips, John Frederick, 33, Tower Wall, East Hartlepool ... (E) Oct. 1892
Purvis, Herbert T., 5, Graingerville, Newcastle-on-Tyne ... ... (E) Oct. 1894

R.

Raincock, Walter, c/o Mrs. Ewart, 8, Washington Terrace, North Shields ... ... (N A) Dec. 1893
Rappoport, Fred. G., 58, Holly Avenue, Jesmond, Newcastle-on-Tyne (E) Mar. 1894
Reid, John Robert, 88, Leslie Terrace, Aberdeen ... ... (E) Nov. 1892
Rickaby, Augustine, Bloomfield Engine Works, Monkwearmouth, Sunderland ... ... (E) Nov. 1885
Rishton, C. William, 17, Denmark Street, Gateshead-on-Tyne ... (E) Nov. 1893
Robinson, Charles O., Ingleside, North Shields ... ... (E) Dec. 1893
Robson, Nathaniel E., 32, North Terrace, Wallsend-on-Tyne ... (E) Dec. 1894
Robson, Robert, 166, Rye Hill, Newcastle-on-Tyne .. .. (E E) Dec. 1894

S.

Scott, Alex. C., Malvern House, Edward's Road, Whitley, Newcastle-on-Tyne ... ... (E) Jan. 1895
Scott, Joseph, 49, Leazes Terrace, Newcastle-on-Tyne ... ... (E) Dec. 1891
Scott, W. A., 100, George Road, Newcastle-on-Tyne ... ... (E E) Oct. 1894
Short, Thomas Smart, c/o Messrs. Short Brothers, Pallion, Sunderland... ... ... (S) Oct. 1892
Simpson, Kenneth, 24, Hartington Street, Barrow-in-Furness ... (S) Dec. 1893
Smith, William S., West Villa, The Green, Wallsend-on-Tyne ... (S) Dec. 1893
Spencer, Harry John, 3, Victoria Street, Newcastle-on-Tyne ... (E) Dec. 1892
Spours, William, 106, Addison Road, Heaton, Newcastle-on-Tyne (E) Nov. 1891
Squire, Charles E., Arnside House, Grosvenor Road, Newcastle-on-Tyne... ... ... (E E) Nov. 1893
Stanger, Thomas W., 38, Addison Road, Heaton, Newcastle-on-Tyne (E) Jan. 1892
Stephens, Henry C. J., 99, Dagnall Park, Selhurst, London, S.E. (E) Oct. 1890
Stephenson, Robert, c/o Messrs. Robt. Stephenson & Co., Limited, South Street, Newcastle-on-Tyne ... ... (E) Mar. 1894
Summerson, Benjamin, Dene Crescent, Walker-on-Tyne, R.S.O. ... (E) Dec. 1892
Swan, George, Messrs. Cooney & Swan, Skippers Street, Belfast ... (E) Mar. 1894

T.

Thomas, Harold, 6, St. John's Road, Stockton-on-Tees ... ... (S) Dec. 1893
Thomas, Robert Gates, 169, Coatsworth Road, Gateshead-on-Tyne (E) Nov. 1894
Tweddell, G. H., 11, Oxford Street, Newcastle-on-Tyne ... ... (E E) May 1894

ELECTED.

V.

Vardy, George, Neptune Engine Works, Walker-on-Tyne... ... (E) Oct. 1894

W.

Wakeham, John F., 50, De Grey Street, Newcastle-on-Tyne ... (S) Mar. 1893
Walker, Gavin Knox, c/o Messrs. Ernest Scott, Mountain, & Co., The Close, Newcastle-on-Tyne ... ... (E) Mar. 1894
Warburton, John A., 15, Northcote Avenue, Sunderland ... ... (E) Mar. 1894
Wawn, T. Noel, 6, Belle Vue, Sunderland ... ... (E) Nov. 1893
Weightman, Thomas, 179, Portland Road, Newcastle-on-Tyne ... (S) Dec. 1892
Wilkin, Ernest Vivian, 11, Appold Street, Finsbury, London, E.C. (E) Nov. 1892
Willcox, Reginald J. N., The Oaks West, Sunderland ... ... (E) Mar. 1892
Wilson, John R. S., Roseworth Tower, Gosforth, Newcastle-on-Tyne (E) Mar. 1894
Wood, John Scott, 6, Eslington Terrace, Newcastle-on-Tyne ... (S) Oct. 1891
Wyand, Fred. W., 13, Eldon Street, Newcastle-on-Tyne ... ... (E E) Oct. 1894

THE NORTH-EAST COAST INSTITUTION

OF

ENGINEERS AND SHIPBUILDERS.

Constitution and Bye-Laws,

ADOPTED AT A GENERAL MEETING ON THE 4TH MARCH, 1885.

REVISED AT THE CLOSING BUSINESS MEETING HELD ON MAY 4TH, 1887.

RE-REVISED AT THE CLOSING BUSINESS MEETINGS HELD ON MAY 9TH, 1888, MAY 13TH, 1889, MAY 11TH, 1891, AND MAY 14TH, 1895.

CONSTITUTION.

I.—The NAME of the Association is "The North-East Coast Institution of Engineers and Shipbuilders." Name.

II.—The OBJECTS for which the Institution is established are :—The advancement of the science and practice of Engineering and Shipbuilding, and the interchange of ideas and information amongst its members, by means of meetings for the reading and discussion of papers relating thereto, and placing on record its transactions. Objects.

III.—The Institution shall consist of Honorary Members, Members, Associates, and Graduates.

IV.—HONORARY MEMBERS shall be such distinguished persons as the Council may elect. Honorary Members.

V.—MEMBERS shall be Principals or Principal Managers engaged in Engineering or Shipbuilding; Civil, Military, or Mining Engineers, or Naval Architects; whose subscription shall be Two Guineas per annum: and other persons engaged in the above professions; whose subscription shall be One Guinea per annum. Members.

VI.—ASSOCIATES shall be such persons as are not strictly Engineers or Shipbuilders, but are connected with or interested in such pursuits, and are deemed by the Council to be eligible for Associate membership. Their subscription shall be One Guinea per annum. Associates.

Graduates.

VII.—GRADUATES may be persons under twenty-four years of age, engaged in study or employment to qualify themselves for any of the above professions. Their subscription shall be Half-a-Guinea per annum.

Life Members and Associates.

VIII.—Any MEMBER may become a LIFE MEMBER by a single payment of Twenty Guineas, or any ASSOCIATE may become a LIFE ASSOCIATE by a single payment of Ten Guineas. All such compositions shall be deemed to be capital moneys of the Institution.

Officers.

IX.—The COUNCIL of the Institution shall be elected from and by the Members, and shall consist of one President, the Past-Presidents, nine Vice-Presidents, fifteen Ordinary Members of Council, and an Honorary Treasurer.

Election of Officers. (See Bye-Law No. 11.)

X.—The President and Honorary Treasurer shall be elected annually. Three Vice-Presidents and five Ordinary Members of Council shall be elected annually. The retiring Vice-Presidents and Ordinary Members of Council shall be those who have served three years from their last election.

The President shall be eligible for re-election for a second year; should he be re-elected he shall retire at the conclusion of his second year of office, and shall not again be eligible until after an interval of one year.

The retiring Vice-Presidents shall be eligible for re-election. The retiring Ordinary Members of Council shall not be eligible for re-election to the same office until after an interval of one year, but shall be eligible for election to any other office.

The Honorary Treasurer shall be eligible for re-election annually, or for election to any other office.

Honorary Members' Privileges.

XI.—Honorary Members may attend all the General Meetings, they may read papers, take part in discussions, in voting, in moving and supporting resolutions, in presentation of notices of motion, or in requisitions for Special Meetings, and in the proposition of new members; they shall also receive copies of the Transactions.

Members' Privileges.

XII.—Members shall have all the privileges of the Institution as enumerated in the foregoing paragraph, and shall be eligible for office.

Associates' Privileges.

XIII.—Associates shall have all the privileges enumerated in paragraph XI. They shall be eligible for office as Ordinary Members of Council.

XIV.—Graduates may attend all the General Meetings, they may read papers, take part in discussions, and support resolutions; they shall also receive copies of the Transactions, but shall not sign proposals for new members, vote, nor be eligible for office. Graduates' Privileges.

XV.—The General Meetings of the Institution shall be held during the months of October to May, inclusive, of each year. General Meetings.

NOTE.—When the word Member is initialled with a capital letter it signifies a member under paragraphs IV. and V., but when initialled with a small letter, it signifies a member of any class of the Institution membership.

BYE-LAWS.

MEMBERSHIP.

1.—Every candidate for admission as a Member, Associate, or Graduate shall be proposed and recommended according to the Form A in the Appendix, in which form the name, usual residence or the place of business, the qualification for, and proposed class of membership of the candidate shall be distinctly specified. Proposals for Graduates must give the date of, and age, last birthday. Candidates for Admission.

The form shall be signed by a Member or Associate of the Institution, as proposer, and by at least other three Members or Associates as supporters, certifying a personal knowledge of the candidate.

The proposal so made shall be submitted to the Council, when, if it be approved, the Chairman shall sign the approbation, which shall be inserted in the notice calling the next General Meeting, when the candidate shall be balloted for, and shall be accepted if three-fourths of the votes are favourable.

2.—Graduates desirous of becoming Members shall be proposed and recommended according to the Form B in the Appendix. Graduates becoming Members

The proposal so made shall be submitted to the Council, who shall agree to or reject it.

3.—The balloting for membership shall be conducted in the following manner:—Each member shall be supplied by post with a list of the names of the candidates, according to the Form C in the Appendix, and shall strike out the names of such candidates as he desires shall not be elected. These lists may be Balloting for Members.

returned to the Secretary by post, or may be deposited in ballot-box by the voter in person on entering a meeting at wh an election is to take place. The ballot-box will be closed ten minutes after the advertised time of meeting. The li shall then be handed over to the Chairman, who shall appo two Scrutineers to examine them, after which examination t Chairman shall inform the meeting of the result.

Candidates to receive Notice of Election.

4.—Notice of Election as a member shall be sent to the ca didate within one week after his election, according to the For D in the Appendix; but his name shall not be added to the li of Members, Associates, or Graduates of the Institution, un he shall have paid his first annual subscription.

Rejection of Candidates.

5.—In case of rejection of the candidate, no mention there shall be made in the minutes, nor shall any notice be given the unsuccessful candidate.

Subscriptions payable in Advance.

6.—All subscriptions shall be payable in advance, and sh become due on the 1st of August each year. Any Memb Associate, or Graduate, wishing to retire from the Instituti shall continue to be liable for his annual subscription until shall have given formal notice of his retirement to the Secreta which notice must be given on or before the 31st of August each year. Application for membership may be made at a time during a Session, and the subscription shall cover t membership up to the 1st of August following.

Receipt of Subscription

7.—On payment of each subscription the Secretary sh forward to the member an official receipt.

Questions of Privilege.

8.—On question of privilege.—Any person who may be u known in the meeting shall only be able to claim the privile in question on proving his membership for the current Session

Arrears of Subscriptions.

9.—Any member whose subscription is one year in arre shall be reported to the Council, who shall direct application be made for it, according to Form E in the Appendix; and the event of its continuing in arrear until the end of th Session after such application, the Council shall have the pow after remonstrance by letter, according to the Form F in t Appendix, of declaring that the defaulter has ceased to be member.

Power of Council to remove Name from List of members.

10.—The Council may refuse to continue to receive the su scriptions of any member who shall have wittingly acted contravention of the Regulations of the Institution, or who sh

in the opinion of the Council, have been guilty of such conduct as shall have rendered him unfit to continue his membership; and the Council may remove his name from the list of members: and such person shall thereupon cease to be a member of the Institution. Notice of such action of the Council shall be forwarded to the person in question, in accordance with the Form G in the Appendix. The reason for such action of the Council shall not be stated to the person expelled, without the sanction of the Council.

OFFICERS.

Election of Officers.

11.—The Annual Election of Officers shall be conducted in the following manner:—The Council shall meet in March or April, and shall arrange a list of nominations, in accordance with the Form H in the Appendix. Such list shall be presented at the General Meeting immediately preceding the last General Meeting of the Session, and any Member present shall be at liberty to nominate additional Members. The list shall show who remain in office throughout the Council, and who are retiring. It shall nominate new names in the place of the retiring Members, and the number of nominations shall be one in excess of the number required in each section of the Council. A copy of this ballot list shall be forwarded to each Member and Associate, together with a complete list of Members, to be filled in, in accordance with the instructions printed in the ballot form, and to be returned to the Secretary, to be opened in the presence of the Council, at a Council Meeting which shall be held in April or May, when the scrutiny and counting shall be carried out by the Council. Any Member in voting shall be at liberty to erase any name or names from the list and substitute the names of any other person or persons eligible for each respective office other than those already placed on the ballot list by the Council and Members of the Institution.

Any voting paper returning either more or less than one President, nine Vice-Presidents, one Honorary Treasurer, and fifteen Ordinary Members of Council, shall be disqualified for the section or sections in which such errors occur, and the votes shall be lost for the said section or sections. The votes given as President, to a Member who is not elected President, shall count to him as a Vice-President; the votes given as Vice-President, or Treasurer, to persons not so elected, shall count to

them as Ordinary Members of Council, unless they have just completed a term of office in such capacity.

The voting list shall not be sent to any Member and Associate whose subscriptions are more than one year in arrear; nor shall any Member be nominated on the list. For this purpose, the Secretary shall prepare, previously to the meeting of Council, a list of those Members whose subscriptions are more than one year in arrears.

Ballot to be declared at May Meeting

12.—The result of the ballot for Officers shall be declared at the Closing Business Meeting, to be held in May, at which meeting general business shall be transacted. At this meeting the newly-elected Officers, after being declared, shall enter into office; and this shall be the last meeting of the Session.

Power of Council to fill up Casual Vacancy.

13.—The Council shall have power to supply any casual vacancy within itself (including any casual vacancy in the office of President), which shall occur between one May Meeting and another; and the Officers so appointed shall retire when the person whose place they fill would have retired. Vacancies not filled up during the year shall be filled at the General Election.

GENERAL MEETINGS.

General Meetings.

14.—The Annual General Meeting shall take place in October, and the Closing Business Meeting in May; each of these meetings shall be held in Newcastle-upon-Tyne. The Ordinary Meetings shall take place in the second week in each following month during the Session, unless otherwise arranged by the Council, and at such hours and places as the Council may determine.

Notice of Meetings.

15.—Seven clear days' notice of every General Meeting, Ordinary or Special, specifying the nature of business to be transacted, shall be given to every member of the Institution.

Special General Meetings.

16.—A Special General Meeting may be convened at any time by the Council, and such meeting shall be convened by the Council whenever such is the declared wish of a General Meeting, or whenever a written requisition, signed by twenty members, specifying the object of the meeting, is left with the Secretary. If, for fourteen days after the delivery of such requisition, a meeting be not convened in accordance therewith, the requisitionists, or any twenty members of the Institution, may convene a Special Meeting in accordance with the requisition. The business discussed at such Special Meetings shall only be that indicated on the notice calling the meeting.

17.—Twenty Members shall constitute a quorum for the purpose of a meeting other than a Special Meeting. Thirty Members shall constitute a quorum for the purpose of a Special Meeting. Quorum.

18.—The President shall be chairman at every meeting, and in his absence, one of the Past-Presidents or one of the Vice-Presidents; or in the absence of these, an Ordinary Member of Council shall take the chair; or if no Member of Council be present and willing to take the chair, the meeting shall elect a Chairman. Chairman at Meetings.

19.—The decision of a General Meeting shall be ascertained by a show of hands; or, when five Members or Associates shall demand, or the Chairman may think it desirable, the decision shall be taken by ballot. The manner of counting the votes shall be at the discretion of the Chairman, and an entry in the minutes, signed by the Chairman, shall be deemed sufficient evidence of the decision of a General Meeting. In cases of equality of votes, the Chairman shall have a casting vote; otherwise he shall not vote. Decisions of General Meetings.

20.—Questions of a personal nature arising in a General Meeting, shall, if possible, be referred to the Council, otherwise the decision of the meeting shall be taken by ballot on a motion or amendment put to the meeting. The ballot shall be taken by the voters (being Members or Associates) writing "for" and "against" on a slip of paper. The slips shall be folded and collected, and then counted in the presence of the meeting, and the result announced by the Chairman. Should fewer than twenty votes be given, it shall be understood that the question is shelved, and the votes shall be destroyed without being opened. Questions of a Personal Nature in General Meetings.

21.—At every General Meeting of the Institution, the Secretary shall first read the minutes of the preceding meeting, which, on approval, shall be signed by the Chairman; business arising out of these minutes shall then be transacted. The Secretary shall read any notices which may have to be brought before the meeting. Notices of motion may then be given, and other business of the Institution may be attended to; but when a paper is to be read, the foregoing business shall not be extended beyond half-an-hour after the advertised time for commencing the meeting. The paper or papers for the evening shall then be read and discussed. Transactions of Business General Meetings.

22.—If within half-an-hour after the time fixed for holding a General Meeting a quorum is not present, the meeting shall be Dissolving a General Meeting.

dissolved, and all matters which might, if a quorum had been present, have been done at the meeting so dissolved, may forthwith be done on behalf of the meeting, by the Council; except the reading or discussion of a paper, which shall not proceed in the absence of a quorum.

Adjourning a General Meeting.

23.—Any General Meeting of the Institution may be adjourned by a vote of the Members and Associates present if there be a quorum; if there be not a quorum, the case shall be met by the preceding paragraph.

Introduction of Friends.

24.—Each member shall have the privilege of introducing one friend to the General Meetings, whose name must be written in the Visitors' Book, together with that of the member introducing him; but if the introducing member be unable to attend the meeting, he may send the name of the visitor to the Secretary. During such portions of any of these meetings as may be devoted to any business connected with the management of the Institution, visitors may be requested by the Chairman to withdraw. This shall be done if five Members or Associates, or both present request it.

COUNCIL MEETINGS.

Council Meetings.

25.—The Council shall meet before each General Meeting, and on other occasions when the President shall deem it necessary, being summoned in either case by circular, stating the time of meeting, and the business, so far as is known.

Convening Meeting for Expenditure of Funds.

No business involving expenditure of the funds of the Institution (except by way of payment of current accounts) shall be transacted at any Council Meeting, unless the circular gives six clear days' notice, and states the business.

Discussions of Personal Character.

All discussions of a personal character in the Council shall be considered and treated as being strictly confidential.

Regulation of Proceedings.

26.—The Council may regulate its own procedure, and delegate any of its powers and discretions to any one or more of its number.

Chairman and Quorum.

The President shall, *ex-officio*, be chairman of all Council Meetings, and in his absence one of the Past-Presidents or one of the Vice-Presidents shall take the chair; or in the absence of these, one of the Ordinary Members of Council shall be elected to take the chair. Five members of Council, including the Chairman, shall form a quorum.

Sub-Committees.

In the appointment of Sub-Committees, the Council shall determine the number which shall form a quorum in each case

and shall appoint a Chairman. These regulations shall not affect the Finance Committee.

27.—The Council may appoint Committees either from itself, or with the assistance of persons outside, for the purpose of transacting any special business, or of investigating specific objects connected with the work and interests of the Institution. **Sub-Committees**

28.—All Committees or Sub-Committees shall be appointed by the Council, and shall be subject to that body, and shall report to it. The Council shall act upon these reports or recommendations as it may think best. The President shall, *ex-officio*, be a member of all Committees. **Sub-Committees.**

29.—Any member may by communication addressed to the Secretary petition the Council to lay before a General Meeting of the Institution the contents of any letter which shall in a short, concise, and clear manner draw the attention of the Institution to public matters of importance in connection with legislation proposed by any governing body in reference to the construction of ships, machinery, or the working of the same, so that members may by their scientific and practical knowledge demonstrate the soundness or otherwise of the proposed measure. **Communication to Council.**

30.—The Council may invite to General Meetings or to Council Meetings any person or persons whose presence and assistance it may desire, and strangers so invited shall be permitted to take part in the proceedings, but not to vote. **Invitation to Strangers.**

31.—The Secretary, who shall also act as Treasurer, shall be appointed by and act under the direction and control of the Council, and shall be paid such salary as the Council shall determine. He shall attend all meetings, Council and General, and shall take minutes of the proceedings, and enter them in proper books provided for the purpose. He shall write the correspondence of the Institution and Council, read minutes and notices at meetings, report discussions, and, if required by the Council, prepare papers for reading and publication, and read papers and communications at the meetings. He shall receive all payments due to the Institution, and shall bank the cash in hand whenever it amounts to ten pounds. The bank shall be determined by the Council and the banking account shall be in the names indicated in connection with the Finance Committee. He shall keep a cash account book, general and detail, which shall on all occasions be open to inspection by the Finance **Secretary and Treasurer's Duties.**

Committee or by the Council. He shall keep a register of the names of members, so arranged as to distinguish all members whose subscriptions are in arrear. He shall also perform whatever other duties are indicated in the Bye-Laws of the Institution as appertaining to his department; and shall remain in office during the pleasure of the Council. He shall not vote on any resolution.

32.—The following Sub-Committees shall be appointed annually at the first meeting of the Council in each Session :—

Finance Committee.

(1) A Finance Committee, to consist of seven persons, viz.: one Past-President or Vice-President, who shall be Chairman; five Members of Council, and the Honorary Treasurer of the Institution; three of whom shall form a quorum. The Treasurer shall be empowered to pay all amounts due from the Institution which are under two pounds. All amounts of two pounds and upwards shall be paid by cheque, signed by the Chairman of the Finance Committee (or in his absence, by the President or a Past-President), the Secretary and the Honorary Treasurer. (2) A Reading Committee, to consist of six members of Council. No member who has served on this Committee for three years in succession shall be eligible for re-election until after an interval of one year. (3) A Library Committee, in accordance with Library Rules, Nos. 1 and 3. (4) A Graduates' Award Committee to consist of five members.

Payment of Accounts.

Reading and Library Committees.

TRANSACTIONS.

Papers to be submitted to Council.

33.—All papers shall be forwarded to the Secretary at least five clear weeks before the proposed date of reading. The Secretary shall submit them for approval to the Council, and on their general approval they shall be handed to the Reading Sub-Committee, three of whom at least, shall read the paper through. The Reading Sub-Committee shall be at liberty to strike out any parts which, in their opinion, ought not to be read. They may also make any suggestions to the author as to points which might with advantage be inserted or altered.

Reading Sub-Committee.

Printing Transactions.

34.—The papers read, and the discussions on them, or such portions of them as the Council shall select, shall be printed for distribution among the members, each of whom shall receive a copy. These Transactions shall be edited by the Secretary, in accordance with instructions of the Council, who shall have

power to omit parts of discussion which may be foreign to the subject, or which it may be deemed undesirable to retain. Each paper shall bear the date on which it was read in General Meeting.

Copy of Papers supplied to members before reading, etc.

35.—Copies of papers to be read during any Session will be sent seven days before the date of reading to members who shall have applied to the Secretary for them, in writing, at the commencement of the Session. The discussion on a paper shall not be considered closed on the evening on which it is read, but shall be open for renewal at a subsequent meeting, prior to the reading of the paper set down for that date.

Proofs sent to members for Correction.

36.—The Secretary shall send to each speaker as soon as possible after a General Meeting a copy in manuscript of the speaker's own remarks for correction. This copy must be returned to the Secretary within four days. A printed proof will also be sent to each speaker for further revision; this must be returned to the Secretary within three days, otherwise it will be deemed correct, and printed off after receiving verbal corrections.

Liberty to Print Explanatory Notes.

37.—The Council shall be at liberty to print as Transactions, either with the papers and discussions or separately, explanatory notes, etc., communicated after the reading or discussing of a paper. Such communications must be approved by the Reading Committee, and shall bear the date on which they shall have been received by the Secretary.

Institution not responsible for statements.

38.—The Institution shall not be held responsible for the statements and opinions advanced in any of the papers which may be read, or in the discussions which may take place at the Meetings of the Institution.

Copies of Transactions to be sent to members.

39.—Twenty copies of each paper and discussion shall be presented to the author of the paper, for private use, and one copy shall be sent to each member. When a paper is prepared by two authors, fifteen copies shall be presented to each. Duplicate copies of parts of the Transactions mislaid or lost by members cannot be supplied to them, except as provided for in Bye-Law 42.

Transactions not supplied to members in Arrears.

40.—The Transactions shall not be supplied free to members whose subscriptions are more than one year in arrear.

Members not to receive Transactions till after First Payment.

41.—Any member elected at any time between the Annual General Meetings shall be entitled to copies of all the Transactions issued during the Session to which his first subscription applies; but not until the subscription has been paid.

Transactions the Property of the Institution.

42.—The Transactions of the Institution shall be the exc sive property of the Institution, and shall be published only the authority of the Council. Additional copies of pap required by authors for their private use can only be procu from the Secretary, at prices fixed by the Council from time time, and these copies must contain the whole of the discuss i following the papers, and be bound in the usual cover, with t addition of the following words:—"By permission of t Council," and "Excerpt Minutes of Proceedings." Duplica volumes and copies of parts of the Transactions, if in print, ca also be obtained from the Secretary, and shall be sold only b him, in such manner and at such prices as the Council sha have fixed.

Rule of Discussion.

43.—During a discussion upon any paper, no person sha be at liberty to speak more than once (except by way of explana tion), nor for a longer period than ten minutes.

ACCOUNTS, &c.

Accounts.

44.—The Council shall present the yearly accounts (up the 31st of July preceding) at the Annual General Meeting October of each year, after they have been audited by a pr fessional Accountant, appointed by the members at the Closi Business Meeting in May.

Trustees.

45.—The capital, stock, and funds of the Institution sh be vested in the names of three Trustees, to be elected from tir to time as vacancies occur by the members of the Institution a General Meeting called for that purpose. All mortgages a other securities shall be taken in the names of such Trustee and on any new appointment the funds shall vest in the newl appointed Trustee or Trustees jointly with the continuing remaining Trustee or Trustees.

Investment of Funds.

46.—The Finance Committee may, with the consent of t Council, invest in the names of the appointed Trustees of t Institution any moneys not immediately required for the pu poses of the Institution, in or upon any approved securities.

ALTERATIONS TO CONSTITUTION AND BYE-LAW

47.—Alteration in or addition to the Constitution and B Laws may be made only by resolution of the members at t

Closing Business Meeting in May, after notice of the proposed alteration or addition has been announced at the previous General Meeting.

The resolution may be modified by the Council meanwhile, should they so desire; but in this case it shall be read at the Closing Business Meeting in May in its original form before it is proposed in the amended form.

Such resolutions shall be stated in the notice calling the intervening Council Meeting, and also in the notice calling the Closing Business Meeting in May.

Vote by Proxy

Any member unable to be present at the meeting at which such alterations are to be considered, but who is nevertheless desirous of recording his opinion thereon, shall be allowed to vote by proxy, such proxies shall be in Form J in the Appendix, which may be had on application to the Secretary, and may be used by any member present at the meeting on behalf of the absent member, and counted by the Chairman as of equal value with votes given in the manner provided in Bye-Law 19.

THE LIBRARY AND READING ROOM RULES.

Committee.

1.—The Library and Reading Room shall be managed by a Committee, called the Library Committee, who shall have charge of all books, papers, specimens, etc., which may belong to the Institution. It shall consist of five members of the Institution, of whom at least two shall be members of Council.

Property.

2.—The books and other property of the Library shall be vested in the Trustees appointed by the Institution.

Appointment of Committee.

3.—The Library Committee shall be appointed annually, at the first meeting of the Council in each Session. No member who has served on the Committee for three years in succession shall be eligible for re-election until after an interval of one year. The Chairman shall be elected by the Council.

Librarian.

4.—The Secretary of the Institution shall be Librarian, and shall also act as Secretary to the Library Committee. Three members of the Committee shall form a quorum.

Duties of Committee.

5.—The Library Committee shall be responsible for the binding and purchasing of books, periodicals, papers, etc., and for the expending of all money voted by the Council for its use. It shall appoint an attendant who shall act as Assistant

Librarian. It shall make Rules for the management of the Library, subject to the approval of the Council, and present an annual report to the first meeting of the Council held after the annual scrutiny of the books referred to in Rule No. 13.

Hours of Opening and Closing, etc

6.—Except when closed by special order of the Library Committee, or when the Council is sitting, the Library and Reading Room shall be open for consulting, borrowing, or returning books, every week day as follows:—On Monday, Tuesday, Wednesday, and Friday, from 10 a.m. to 12 noon, and from 1 to 9 p.m.; on Thursday, from 10 a.m. to 12 noon, and from 1 to 5 p.m.; on Saturday, from 10 a.m. to 1 p.m., and from 2·30 to 9 p.m. The Rooms will be closed on Christmas Day and the day following, New Year's Day and the day following, Good Friday, Monday and Tuesday in Easter week and Whit week, and the first Monday in August (being Bank Holiday); also at noon on Tuesday, Wednesday, Thursday and Friday in the Race week of June, and from the second to the fourth Saturday in July of each year, as mentioned in Rule No. 13.

Lending of Books.

7.—Books shall not be lent to any persons except Members, Associates, or Graduates of the Institution, but a person entitled to borrow a book may send a messenger with a signed order for it.

Visitors.

8.—Each member shall be entitled to introduce a friend to the Reading Room, whose name shall be written in the Visitors' Book, together with that of the member introducing him.

Reference Books.

9.—The books marked with an asterisk in the Catalogue shall be kept only for consultation in the Library, and shall not be lent. Pending the preparation of a Catalogue, the Librarian shall be instructed by the Committee as to which books shall be withheld from circulation.

Unbound Books.

No periodicals, magazines, or pamphlets shall be issued for circulation until after they have been bound and added to the Lending Library.

Register of Books Lent, etc.

10.—The Librarian shall keep a register in which he himself or the attendant shall enter the titles of the books lent, the date of lending, the name of the borrower, and the date of the return of the book to the Library. The borrower of the book or the bearer of his order shall initial the entry of such borrowing, and the Librarian or the attendant shall initial the date of the return of the book.

11.—No person shall borrow or have in his possession at one time more than two volumes belonging to the Library. **Number Lent to each member.**

12.—No member shall retain a book longer than fourteen days, excluding the day of issue. He shall be responsible for the safe return of the book, and if it be damaged or lost he shall make good the cost of such damage or loss. **Return of Books.**

13.—All books belonging to the Library shall be called in for inspection, and the lending out of books shall be suspended from the second to the fourth Saturday of July, inclusive, of each year, and members shall be required by notice to return all books in their hands before the period mentioned. **Yearly Inspection of Books.**

Members failing to comply with this injunction shall pay a fine of two shillings and sixpence. **Fine.**

14.—Members are requested, when in the Reading Room or Library, to contribute to the general comfort by carefully abstaining from loud talking and noise of any kind. Smoking is not permitted in the Library.

15.—Any member being twelve months in arrears with his subscriptions to the Institution shall not be at liberty to use the Library or Reading Room after the commencement of the first Session following. **Members in Arrears.**

N.B.—The foregoing Rules may be amended at any time by the Library Committee with the sanction of the Council.

APPENDIX TO BYE-LAWS.

FORM A. (BYE-LAW 1.)

Name (in full)
Profession or Occupation and where Employed
Address
being desirous of admission into the North-East Coast Institution of Engineers and Shipbuilders, we, the undersigned, propose and recommend that he shall become*
thereof. We know him to be†
and eligible for the proposed membership.

* A Member, Associate, or Graduate.
† A Principal, Manager, or Draughtsman, etc. See Articles V., VI., and VII. of Constitution.

	FROM PERSONAL KNOWLEDGE.	SECTION OF MEMBERSHIP.
Proposed by		
Supported by Three Members or Associates.		

Dated this day of

(When a Graduate is proposed the age last birthday should be stated.)

FORM B. (BYE-LAW 2.)

A. B. [Christian Name, Surname, Occupation and Address in full] being at present a of the North-East Coast Institution of Engineers and Shipbuilders, and upwards of twenty-four years of age, and being desirous of becoming a of the said Institute, we, the undersigned [Members or Associates], recommend him, from *personal knowledge*, as a person eligible for the proposed Change of membership, because—

(Here specify distinctly the Qualifications of the Candidate according to the spirit of the Rules of the Institution.)

Signed _____ } Three [Members or Associates.]
_____
_____

Dated this day of 18

FORM C. (BYE-LAW 3.)

BALLOTING PAPER FOR MEMBERSHIP.

The Council having considered the recommendations for Membership of the following gentlemen, present them to be balloted for, viz.:—

Member, Associate, or Graduate.	Occupation.	Address.	Nominated by.	Supported by Three Members or Associates.

Strike out the names of such persons as you desire shall *not* be elected, and forward the list by post to the Secretary, or personally place it in the ballot-box at the Meeting.

FORM D. (BYE-LAW 4.)

Sir,—I am directed to inform you that on the day of you were elected a of the North-East Coast Institution of Engineers and Shipbuilders, but, in conformity with Bye-Law 4, your election cannot be confirmed, nor your name be added to the roll of membership, until you have paid your first annual subscription, the amount of which is £ : : , or, at your option, the Life Composition of £ : : .

Payment may be made to the Treasurer, Mr. _____

Address _____

I am, Sir,

Yours faithfully,

Secretary.

Dated 18

N.B.—In case of a Graduate, strike out "*or, at your option, the Life Composition of* £ : : "

FORM E. (BYE-LAW 9.)

SIR,—I am directed by the Council of the North-East Coast Institution of Engineers and Shipbuilders to draw your attention to Bye-Law 6, and to remind you that the sum of £
of your annual subscriptions remains unpaid, and that you are in consequence in arrear of subscription.

I am also directed to request that you will cause the same to be paid without further delay, otherwise the Council will be under the necessity of exercising their discretion as to using the power vested in them by the Rule above referred to.

I am, Sir,
Yours faithfully,

Secretary.

FORM F. (BYE-LAW 9.)

SIR,—I am directed by the Council of the North-East Coast Institution of Engineers and Shipbuilders to inform you that in consequence of non-payment of your arrears of subscription, and in pursuance of Bye-Law 9, the Council have determined that unless payment of the amount (£) is made previous to the day of next, they will proceed to declare that you have ceased to be a member of the Institution.

But, notwithstanding this declaration, you will remain liable for payment of the arrears due from you.

I am, Sir,
Yours faithfully,

Secretary.

FORM G. (BYE-LAW 10.)

SIR,—I am directed by the Council of the North-East Coast Institution of Engineers and Shipbuilders to inform you that they feel it their duty to advise you to withdraw from the Institution, or otherwise they will be obliged to act in accordance with Bye-Law 9 (or 10, as the case may be).

I am, Sir,
Yours faithfully,

Secretary.

FORM H. (BYE-LAW 11.)

BALLOTING LIST.

PRESIDENT.—ONE NAME only to be returned, or the vote will be lost.

——— President for the current year (eligible for re-election.)*

——— } New Nominations, from whom to select ONE.

VICE-PRESIDENTS.—NINE NAMES only to be returned (including the six who remain in office), or the vote will be lost.

——— } Six Vice-Presidents remaining in office, whose seats are NOT vacant.

——— } Three Vice-Presidents retiring, eligible for re-election.

——— } New Nominations, from whom to select THREE names.

TREASURER.—ONE NAME only to be returned, or the vote will be lost.

——— Treasurer for the current year, eligible for re-election.

——— } New Nominations, from whom to select ONE.

ORDINARY MEMBERS OF COUNCIL.—FIFTEEN NAMES only to be returned, including the ten who remain in office.

——— } Ten Ordinary Members of Council remaining in office. These do not require to be voted for at this election, as their term of service has NOT yet expired.

——— } Five Ordinary Members of Council retiring, and NOT eligible for re-election.

——— } New Nominations, from whom to select FIVE.

* To be crossed out before issue, when the President is not eligible for re-election.

N.B.—(*a*) The names of those who remain in office will be counted in the total number required without being re-written by the voter.

(*b*) Any list having either MORE or LESS than the required number of names voted for in any section will be disqualified for that section.

(*c*) Votes as President for a person who is not elected will count for him as a Vice-President.

(*d*) Votes as Vice-President, or Treasurer, for persons not so elected, will count for them as Ordinary Members of Council, unless they have just completed a term of office in that capacity.

(*e*) This list, duly filled in, may be returned to the Secretary by post, or handed to him, so as to be on the Council table before the commencement of the scrutiny, which is appointed to take place in the Council Room, at 8 p.m., on 18

(*f*) A copy of this list shall be posted at least Seven Days previous to the Annual Meeting to every Member and Associate, who may erase any name or names from the list and substitute the name or names of any other person or persons eligible for such respective offices, but the number of persons on the list after such erasure or substitution must not exceed the number to be elected to the respective offices.

Secretary.

FORM J. (BYE-LAW 45.)

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

FORM OF PROXY.

FOR VOTES ON ALTERATIONS TO CONSTITUTION OR BYE-LAWS.

I,....., being [an Honorary Member, Member, or Associate] of the above Institution, do hereby appoint Mr..... who is [an Honorary Member, Member, or Associate] of the same Institution, to act as my Proxy, and record my Vote at the General Meeting of the Institution, to be held on the... .....day of ....., 18....., and at any adjournment thereof.

Signature.....

Address.....

.....

.....*Secretary.*

NORTH-EAST COAST INSTITUTION

OF

ENGINEERS AND SHIPBUILDERS.

ELEVENTH SESSION, 1894-95.

PROCEEDINGS.

ELEVENTH ANNUAL MEETING OF THE INSTITUTION, HELD IN THE LECTURE HALL OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-UPON-TYNE, ON TUESDAY EVENING, OCTOBER 16TH, 1894.

ALDERMAN THOS. RICHARDSON, B.A., J.P., PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the Closing Business Meeting of the tenth session, held in Newcastle-upon-Tyne, on May 8th, 1894, which were approved by the members present, and signed by the President.

The ballot for new members having been taken, the President appointed Messrs. W. Boyd and G. E. Macarthy to examine the voting papers, and the following gentlemen were declared elected :—

MEMBERS.

Bredsdorff, Thomas, Shipbuilder, Messrs. Flensburg Shipbuilding Co., Flensburg, Germany.

Camps, H. E. J., Naval Architect, 16, Ravensbourne Terrace, South Shields.

Chaston, Edwd. Catmore, Assistant Engineering Surveyor, 45, Cardigan Terrace, Heaton, Newcastle-on-Tyne.

Cherry, Thos. Wm. Fry, Engineer Draughtsman, c/o Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's, Newcastle-on-Tyne.

Downing, Nicholas, Master Ironfounder, Oxford Terrace, Norton Road, Stockton-on-Tees.

Greenhow, John, Assistant Shipbuilding Manager, 9, Rowell Street, Hartlepool.

McLaren, William, Superintendent Engineer, 8, London Grove, Prince's Road, Liverpool.

Mair, James, Wh. Sc., Mechanical Engineer, 5, Cleveland Road, North Shields.

Reed, Richard, Ship Draughtsman, 36, Chillingham Road, Heaton, Newcastle-on-Tyne.

Trowell, Wm. John, Engineer, 37, Caroline Street, Jarrow-on-Tyne.

Topp, Carl, Shipyard Manager, Schichau Werfl, Danzig, Germany.

Turnbull, Charles, Jun., Electrical Engineer, Hilton Lodge, North Shields.

Warden, Thomas M., Engineer Manager, 21, Windermere Street, Gateshead-on-Tyne.

Weir, George Dobie, Engineer Draughtsman, Northumberland Engine Works, Wallsend-on-Tyne.

Wheater, Chas. Busfield, Engineer Draughtsman, 18, Westmoreland Terrace, Newcastle-on-Tyne.

MEMBERS (LATE GRADUATES).

Adamson, Daniel, Mechanical Engineer, c/o Messrs. Joseph Adamson & Co., Hyde.

Gaine, Roger L., Engineer Draughtsman, 62, Harrison Street, Barrow-in-Furness.

Gibson, J. Hamilton, Engineer, 12, Bratlan Road, Birkenhead.

ASSOCIATES.

Lloyd, John, Cashier, Deptford Shipyard, Sunderland.

Nixon, John, Commercial Manager, c/o Messrs. Blyth Shipbuilding Co., Blyth.

GRADUATES.

Adams, Dawson, Electrical Engineer, 20, Brinkburn Terrace, Westoe, South Shields.

Binns, Aubry B., Apprentice Marine Engineer, 23, Thornhill Terrace, Sunderland.

Crombie, W. Alan D., Apprentice Electrical Engineer, 13, Eldon Street, Newcastle-on-Tyne.

Featherstonhaugh, Albany, Apprentice Engineer, 13, Park Place West, Sunderland.

Hisk, Charles, Apprentice Marine Engineer, 21, Sea View Terrace, South Shields.

Purvis, Herbert T., Draughtsman, 5, Graingerville, Newcastle-on-Tyne.

Scott, Wm. A., Apprentice Mechanical and Electrical Engineer, 100, George Road, Newcastle-on-Tyne.

Vardy, George, Apprentice Engineer, Neptune Engine Works, Walker-on Tyne.

Wyand, Fred. W., Apprentice Electrical Engineer, 13, Eldon Street, Newcastle-on-Tyne.

The SECRETARY read the Tenth Annual Report of the Council, which, together with the Financial Statement, was submitted to the meeting.

COUNCIL REPORT.

(TENTH SESSION, 1893-94.)

The Council has pleasure in placing before the Institution the statement of accounts for the past year, from which it will be seen that the financial position of the Institution is still satisfactory, but regrets to state that the amount of subscriptions in arrears is higher than usual. The Council is of opinion that this is detrimental to the dignity of the Institution.

The balance from the previous statement for the year ending March 31st, 1893, was £949 7s. 11d., £388 2s. of which being donations towards the stipend of the Professor of Naval Architecture and Marine Engineering in the Durham College of Science.

The Council has thought fit to place the sum of £400 to deposit account on interest with the bankers, Messrs. Woods & Co., of Newcastle-upon-Tyne, on behalf of the Durham College of Science. During the past year a further sum of £394 9s. has been collected towards this fund, out of which £230 has been paid over to the College, leaving a total balance of £552 11s. to be dealt with by the Council, the Institution having now completed its guarantee to the College to pay the sum of £230 per annum for three years.

The Council has also invested the sum of £500 belonging to the Institution with the River Tyne Commissioners for a period of 15 years, bearing interest at the rate of $3\frac{3}{4}$ per cent. per annum.

The measured mile posts at Hartley having shown signs of decay it was necessary to repair them; but the severe gales of November and February last damaged them to such an extent that it has now been found necessary to renew the present posts; and arrangements are being made for replacing these by a set made of iron, the cost of which, together with the amount already spent in repairs, £55 1s. 9d., will not be defrayed out of the funds of the Institution, but will be obtained from the shipbuilding and engineering firms in the district.

The tenth session was opened by a conversazione given by the President, Mr. Robert Thompson, J.P., which was attended by a large

assemblage of members and friends. At this sociable and enjoyable gathering the President presented the two Institution Gold Medals for the ninth session to the successful candidates, viz. :—The Shipbuilding Medal to Mr. S. O. Kendall, for his paper on "Strains of Tank Steamers," and the Engineering Medal to Mr. J. Denholm Young, for his paper "On a System of Mechanical Aid to the Investigation of Speed Curves."

A communication having been received from the Marine Department of the Board of Trade calling attention to a resolution passed by the Institute of Marine Engineers in London with regard to the term of apprenticeship for marine engineers, and intimating they would be glad to receive any observations thereon. The Council deputed Mr. J. R. Fothergill, Vice-President, to write a paper on the subject, with a view of bringing the matter before the whole body of the Institution, and giving the members an opportunity of expressing their opinions upon the questions involved. This was done, two evenings were occupied in the discussion, and in accordance with a resolution passed at the general meeting, held on January 30th, 1894, a reply was drawn up by the Council, and forwarded to the Marine Department of the Board of Trade. A copy of the reply will be found on page 269, vol. X., of the *Transactions*.

During the session the following papers were read and discussed :—

"On a Method of Comparing Steamship Performances and of Estimating Powers and Speed of Ships." By Mr. W. Hök, Member of Council.

"On the Dangerous Working Heat of Mild Steel, and the Effect of Annealing and Air Cooling." By Mr. Joseph Nodder.

"On certain Principles of Motion as Taught by the Pendulum, and as Illustrated by the Resistance of Ships and other Bodies Moving through Fluids," etc. By Mr. Frank Caws.

"Mercantile Marine Engineers." By Mr. J. R. Fothergill, Vice-President.

"On a New System of Construction for Large Vessels of Cellular Type." By Mr. William Bell.

"Oil Engines." By Mr. William Stafford.

"Bases for Classification of Vessels Proportioned to their Strength to Resist Bending and Vibration." By Mr. Arthur Liddell.

During the year the Graduates have held six general meetings, and the Council, while regretting having to report that the average attendance at these meetings has been less than that of the previous sessions, has pleasure in stating that the papers read were quite up to, if not superior, to those previously given, and it is hoped that for the future the Graduate Members will do their utmost to support this useful section of the Institution.

In this section the following papers were read and discussed :—

"Marine Boiler Design." By Mr. R. L. Gaine.
"Ship's Pumping Arrangements." By Mr. W. Oxton.
"Notes on Ship Launching." By Mr. A. Young.
"Pumping Machinery." By Mr. C. Bryers.
"High Speed Engines." By Mr. A. L. Foster.
"Pumps, with Special Reference to those for Ships' Use." By Mr. E. T. White.

Visits were also paid to the following places of interest :—

The Wallsend Slipway and Dry Dock.
Pandon Dene Electric Supply Station.
Hendon Paper Mill.
Messrs. Hawthorn, Leslie, & Co.'s Engine Works, St. Peter's.
Dunston Flour Mills.

The thanks of the Institution are due to the principals and officials of the above works for their kindness and courtesy shown on each occasion towards these younger members of the Institution.

The prizes for the best papers read in this section during the ninth session were awarded as follows :—

First award to Mr. John King for his paper on "Floating Caissons." The second award was divided between Mr. A. Young, for his paper on "A Modern Theory of the Rolling of Ships," and Mr. J. Brentnall Duckitt, for his paper on "Continuous Current Dynamos."

During the past year the following additions have been made to the list of members, viz. :—50 Members, 16 Associates, 1 Life Associate, and 39 Graduates; and 16 Graduates have been raised to the rank of Members.

The Institution regrets having to record the loss by death of the following :—Messrs. Thos. Carter, J. Noble, Frank Pool, and Anthony Proud, Members; and Mr. William Boyd, Jun., Graduate.

It has also lost from resignations and other causes 23 Members, 6 Associates, and 12 Graduates.

The total number of members of all classes now enrolled on the books of the Institution is 954, as follows :—

Honorary Members	3
Life "	5
Ordinary "	717
Life Associates	2
Associates	111
Graduates	116
Total	954

Considerable additions have been made to the lists of books in the Library, and the following donations have also been received :—

Presented by	
Mr. Wm. Cooper ...	*Diaries of Sir Daniel Gooch, Bart.*
	From Keel to Truck. H. Paasch. 1885.
	Light. Lewis Wright.
	Spectator. Ed. H. Morley.
	Spon's Dictionary of Engineering, 8 vols. 1874.
Mr. John Duckitt ...	*Liverpool Polytechnic Society.* Sessions 28 to 36. 1865-1873.
Mr. J. M. F. Tone ...	*Proceedings, Institution Civil Engineers.*
	Pamphlets, 1837-52. 7 vols.
	Index, 1865.
	Catalogues, 1851, 1865, 1870, 1871.
	Report, 1871.
	Vols. 17, 21, 26 to 34, 50, 53, 54.
Mr. W. H. White ...	*Naval Architecture.*
Mr. Harry Gray ...	12 parts *Practical Magazine* (unbound).
	Engineering, vols. 25, 26, and 27 (bound); vols. 28, 29, 30, 31, and 32 (unbound); July-Dec., 1879, to July-Dec., 1885; 5 vols. complete except No. 713, Aug. 29, 1879.

In response to the kind invitation received by the Council from Messrs. The Consett Iron Company, a visit was made to the Consett Iron Works on Thursday, July 19th, 1894. The members were cordially received and hospitably entertained, on behalf of the Company, by Mr. David Dale, Chairman; Mr. Thos. Bainbridge, Director; Mr. G. Ainsworth, General Works Manager; and Mr. H. Holliday, Secretary and Commercial Manager.

Considerable interest has been taken by the Council in the endeavour to obtain for the Engineering Laboratory of the Durham College of Science a set of Experimental Quadruple Expansion Engines and Boiler.

The several parts of the engines and boiler have been supplied as gifts by the various engineering and shipbuilding firms in the district and other firms; and owing to the indefatigable endeavours of Mr. Robert Thompson (Past-President), Mr. John Gravell, and Professor R. L. Weighton (Vice-Presidents), the work is completed, and the engines are now erected in the College Laboratory.

LIST OF SUBSCRIPTIONS

RECEIVED TOWARDS THE SALARY OF THE PROFESSOR OF ENGINEERING AND NAVAL ARCHITECTURE IN THE DURHAM COLLEGE OF SCIENCE, NEWCASTLE-ON-TYNE. FROM AUGUST, 1893, TO AUGUST, 1894.

	£	s.	d.
Sir William Gray, West Hartlepool	30	0	0
Messrs. Wigham Richardson & Co., Walker-on-Tyne ...	30	0	0
„ Palmer's Shipbuilding Co., Jarrow-on-Tyne ...	30	0	0
„ John Readhead & Sons, South Shields	25	0	0
„ C. S. Swan & Hunter, Wallsend-on-Tyne ...	25	0	0
„ George Clark, Limited, Sunderland	20	0	0
John Dickinson, Esq., Sunderland...	20	0	0
Messrs. W. Doxford & Sons, Sunderland	20	0	0
James Laing, Esq., Sunderland	20	0	0
Charles Mitchell, Esq., Newcastle-on-Tyne	20	0	0
Messrs. N. E. Marine Engineering Co., Wallsend-on-Tyne	20	0	0
„ J. L. Thompson & Sons, Sunderland	20	0	0
„ The Wallsend Slipway Co., Wallsend-on-Tyne ...	20	0	0
„ The Sunderland Shipbuilding Co., Sunderland ...	15	0	0
Arthur Coote, Esq., Newcastle-on-Tyne	10	0	0
Messrs. J. Eltringham & Co., South Shields	10	0	0
„ John Spencer & Sons, Newburn-on-Tyne ...	10	0	0
„ Clarke, Chapman & Co., Gateshead (2 years' subscription)	10	0	0
„ W. Hepple & Co., South Shields (2 years' subscription)	10	0	0
John Gravell, Esq., Newcastle-on-Tyne	5	0	0
Messrs. J. P. Rennoldson & Co., South Shields	5	0	0
„ Smith's Dock Co., North Shields	5	0	0
„ Westgarth, English, & Co., Middlesbrough ...	5	0	0
„ Baird & Barnsley, North Shields	3	3	0
G. E. Macarthy, Esq., Newcastle-on-Tyne	2	2	0
Messrs. J. Priestman & Co., Sunderland	2	2	0
G. W. Sivewright, Esq., Hartlepool	2	2	0
	£394	9	0

NORTH-EAST COAST INSTITUTION OF
STATEMENT OF RECEIPTS AND PAYMENTS

Receipts.

		£ s. d.	£ s. d.
To Balance from last Account—			
At Bankers		938 15 2	
In hand		10 12 9	
			949 7 11
„ Subscriptions received for Session 1893–94—			
229 Members at £2 2s.	£480 18 0		
428 Members „ £1 1s.	449 8 0		
111 Associates „ £1 1s.	116 11 0		
100 Graduates „ 10s. 6d.	52 10 0		
868		1,099 7 0	
„ Arrears for Sessions 1890 to 1893—			
7 Members at £2 2s.	£14 14 0		
32 Members „ £1 1s.	33 12 0		
4 Associates „ £1 1s.	4 4 0		
8 Graduates „ 10s. 6d....	4 4 0		
		56 14 0	
			1,156 1 0
„ Life Associate, R. Henzell			10 10 0
„ Transactions sold this Session		19 16 3	
„ Copies of Members' Papers supplied		10 18 6	
			30 14 9
„ Tyne Improvement Commissioners—			
One Year's Interest to 21st June, 1894, on £605, at 3½ per cent.		21 18 6	
Viz.:—Medal Fund	£274 0 0		
Graduates' Award and Life Members' Fund	331 0 0		
	£605 0 0		
Less—Tax		0 13 1	
			21 5 5
Half-year's Interest to 10th July, 1894, on £500, at 3½ per cent.		9 7 6	
Less—Tax		0 5 10	
			9 1 8
„ Chair of Engineering and Naval Architecture Fund—			
Donations as per list			394 9 0
„ Balance from Leeds Excursion			3 14 0
			£2,575 3 9

ENGINEERS AND SHIPBUILDERS.

FOR SESSION ENDING 31ST MAY, 1894.

Payments.

	£	s.	d.	£	s.	d.
By Transactions and Papers—						
Lithographing	107	6	6			
Printing and Binding	215	2	6			
				322	9	0
„ Stationery and Circulars	82	15	11			
„ Reporting	23	14	0			
„ Rents—						
Offices	65	4	0			
Lecture Rooms	5	14	0			
Telephone	8	0	0			
„ Rates, Gas, and Insurance	15	13	3			
„ Salaries—						
Secretary, Salary	220	0	0			
Do. Commission	58	6	6			
Assistant Librarian	35	0	0			
Office Boy	10	0	0			
„ Postages, Stamps, Post Cards, Parcels, etc.	97	9	4			
„ Secretary's Expenses and Allowances to Hall Keepers, etc.	27	11	7			
„ Office Expenses, Coals, Cleaning, etc.	14	9	6			
„ Rent for Measured Mile Posts	3	3	0			
„ Repairs to „ „	55	1	9			
„ Expenses of Graduates' Meetings and Hire of Lantern ...	1	11	9			
„ Auditor's Fee	3	3	0			
				726	17	7
„ Jamas Bacon—						
Photographs of President and Past-Presidents... ...				21	12	6
„ Library Account—						
New Books	15	5	0			
Bookbinding	7	5	9			
				22	10	9
„ Chair of Engineering and Naval Architecture Fund—						
One Year's donation towards Salary of Professor ...				230	0	0
„ Gold Medals' Fund (Two Medals Awarded)	9	10	0			
„ Graduates' Award Fund—Amounts Awarded for Papers...	7	12	6			
				17	2	6
„ Woods & Co.—Amount on Deposit from Chair of Engineering and Naval Architecture Fund				400	0	0
„ Tyne Improvement Commissioners.—Amount Lent on Mortgage of the Tyne Consolidated Fund for 15 years at 3¾ per cent Interest....				500	0	0
„ Balance—						
At Bankers...				334	11	5
				£2,575	3	9

THE BALANCE SHEET.—FOR THE SESSION ENDING 31ST MAY, 1894.

Liabilities.

		£ s. d.	£ s. d.
Chair of Engineering and Naval Architecture Fund—			
Amount as per previous Account	£388 2 0		
Donations, 1893-94 ...	394 9 0		
		782 11 0	
Less Amount Paid to Durham College of Science		230 0 0	
			552 11 0
Gold Medals' Fund—			
Amount at 31st May, 1893 ...	£281 10 11		
Interest on Investment ...	9 12 8		
		291 3 7	
Less—2 Gold Medals		9 10 0	
			281 13 7
Graduates' Award Fund—			
Amount at 31st May, 1893 ...	£223 7 5		
Interest on Investment ...	7 11 9		
		230 19 2	
Less—Awards for Papers		7 12 6	
			223 6 8
Payments by Life Members and Associates—			
Amount at 31st May, 1893		115 10 0	
Payment this Session		10 10 0	
			126 0 0
General Capital			1,205 8 8
			£2,388 19 11

Assets.

	£ s. d.	£ s. d.
Subscriptions in Arrear—		
Session 1890-91	2 2 0	
„ 1891-92	2 2 0	
„ 1892-93	14 14 0	
„ 1893-94	98 3 6	
		117 1 6
Stock of Transactions, valued at		151 9 4
Office and Library Furniture, Safe, etc., as at 31st May, 1893	121 14 11	
Less Depreciation	12 3 6	
		109 11 5
Books in Library—		
As at 31st May, 1893 ...	£165 6 1	
Less Depreciation ...	16 10 7	
	148 15 6	
Additions this Session	22 10 9	
		171 6 3
Tyne Improvement Commissioners—Investment in respect of the following Accounts, viz.:—		
Gold Medals' Fund	274 0 0	
Graduates' Award Fund	215 15 0	
Payments by Life Members and Associates	115 5 0	
General Capital	500 0 0	
		1,105 0 0
Woods & Co.—Amount on Deposit, being part of Fund for Chair of Engineering and Naval Architecture		400 0 0
Cash—At Bankers		334 11 5
		£2,388 19 11

Audited and certified,

Mr. F. C. Marshall moved the adoption of the Council Report and Financial Statement. He said it was not very creditable that members of that Institution should be so very much in arrears with their subscriptions. It was scarcely worthy of the Institution or of the district. Let them hope that that would be remedied as soon as possible. The report was very voluminous and complete. He would like to say something with reference to the mile posts at Whitley. They had got very much out of repair. The Council had undertaken to get them put into decent repair, and put into such a condition that they could be seen at some distance at sea. Personally, he hoped that that would be very speedily done, because the tendency at present was to send ships on trial round to Skelmorlie on the Clyde, and to do that was rather *infra dig.* to the North-East Coast shipbuilders and engineers. It was very gratifying to know that that Institution was being made the means of carrying out such a valuable adjunct to their work. He had great pleasure in moving the adoption of the report.

Mr. Robert Thompson seconded. He said he had great pleasure in seconding the motion for the adoption of the Council report. It was a fair report of the year's work. It indicated what they had done, and the changes that took place in institutions of that kind. They had to deplore the loss of some of their members by death; they were liable to these changes, but on the other hand they had an increased total membership due to the growing influence of the Institution.

The motion was put by the President and carried.

The President, on rising, said before he proceeded to read his address, he should just like to take that opportunity of again thanking the members of the Institution for the very great honour they had conferred upon him in electing him their President. He could assure them all that he should very heartily devote himself to the best interests of the Institution, and he thought when he remembered the work that had been done by those who occupied the position he now occupied, backed up by a very able Council—a Council which he had already had the honour to preside over—that he could with every confidence occupy that position, for he felt that the work that had been done before would considerably lighten the task which devolved upon his shoulders. He should like to congratulate them all on the steady progress which that Institution made from session to session. He thought when they looked back on the work done last session that they had every reason to look forward to the future

with confidence. He was very pleased that Mr. Marshall had referred to the measured mile posts, and what had been done in regard to them by that Institution. They had several times, as it were, stepped out of their province to do work, and they had not only done it well, but the work itself was work they would have had great difficulty in getting done at all. These measured mile posts came under that head. There was also, he thought, the money that they had guaranteed to the chair of professorship at the Durham College of Science, also the engines handed over to the college by his predecessor, Mr. Robert Thompson, who had worked so hard and so successfully in the interests of the Institution during his term of office. He thought they would agree with him that these things had been satisfactorily carried through, and reflected great credit to all concerned.

The PRESIDENT then delivered his Inaugural Address :—

PRESIDENT'S INAUGURAL ADDRESS.

By Alderman THOS. RICHARDSON, Esq., B.A., J.P.

[Delivered in Newcastle-upon-Tyne, on October 16th, 1894.]

Closely associated as I have been all my life with an engineering works started more than half a century ago, and increasing in size with the growth of the trade of the district until it has become one of the largest marine engine works on the North-East coast, I have had by tradition and experience continually before me the difficulty of always keeping up to date with machinery and meeting the demands of labour, and great as this task often has been in the past, I can recall no time so discouraging and difficult as the present. We have had to contend with bad trade, with disputes between capital and labour, but I remember no period when we have had pressure from both troubles to contend with at the same time, making the successful carrying on of industrial concerns an impossibility.

Those of you who are directly associated with the engineering and shipbuilding industries will readily appreciate that the subject of economical production is one to which more than usual prominence has lately been given by the recent almost complete stoppage of work on this coast, by one of those disastrous disputes between capital and labour which are now so frequent. It is not my province, as President of an Institution such as ours, to dilate on the inevitable result of such disputes, but rather to seek for a counteracting element in order to do our part in postponing the day when the industries with which we are connected will, instead of being in the proud position they were a few years ago, be crushed into comparative insignificance, if an end is not put to these suicidal conflicts.

Another factor which is year by year becoming more prominent is the competition of foreign countries, and the unfortunate doctrine which is so often sensationally made use of as to our superior capacity as handicraftsmen is by no means so true now as formerly. The extended and universal adoption of machinery has been the chief cause of this levelling up, and particularly is this the case in the engineering industry where the scope for the application of machinery is practically unlimited.

It is not enough, however, to apply machinery, but to develop it, as the one remedy for survival is continuous evolution; although the unconscious fascination which is often associated with old tools and old methods often renders the evolution dangerously intermittent. It is apparently this fascination, combined with an unselfish desire to satisfy the cravings of the shipowner for propelling machinery requiring the least possible consumption of coal, which is responsible for the fact that whilst we build engines and boilers consuming 1½ lbs. of coal per I.H.P. per hour, we drive the machinery in our workshops at an expenditure of fuel four to six times greater in amount. This is, of course, attributable to the use of a number of high-pressure non-condensing engines distributed over a large area, and supplied with steam through long lengths of piping from a central group of boilers. Here, then, is a field in which economies are to be obtained, and one of the best solutions appears to be the application of electrical driving.

In the able address of Prof. Kennedy before the Institution of Mechanical Engineers this subject was very fully dealt with, and at the late meeting of the Iron and Steel Institute at Brussels a very interesting and instructive paper was given by Mr. Selby Bigge, which conclusively showed the importance and possibilities of the system. At the risk of rendering this address narrow, and more in the form of a paper, rather than general, I propose to give some illustrations of the application of electrical driving, both in this country and abroad, hoping that a *résumé* of what has actually been accomplished may promote a discussion which will help to ventilate the question and be fruitful in beneficial results. With the late disastrous record of the shipbuilding and engineering industries, as an example, it is highly improbable that any capitalist will start a new shipyard or engine works amongst us, so that we may be sufficiently selfish to consider the application of electrical driving to existing works only. The first question to consider, therefore, is that having boilers grouped in one place from which steam is led to engines distributed over large area, what economy can be expected from substituting for those engines electric motors supplied with power from a central station, and will the results justify the expenditure? We are all thoroughly aware that condensation does occur in steam pipes, and that the present engines are uneconomical, but a broad view is generally taken of the matter, and little has been done to ascertain what the results really are. It is for this reason that the experiments and developments made by Mr. Panton and Messrs. Dorman, Long, & Co., of Middlesbrough, in conjunction with Mr. Selby Bigge, are of the greatest value, and particularly so as they have

resulted in complete success. The original steam driven machinery comprised punching, shearing and bending machines, cold saws, etc., all of which were distributed over a large area and driven by six engines capable of indicating the following powers, viz.:—27, 14, 14, 14, 16, and 9. These engines were disconnected and replaced by motors of 10½, 3½, 5, 3½, 3½, and 3½ horse-power respectively, the driving gear consisting of a belt from the motor direct to the fly-wheel of the machine. The most noticeable case is that illustrated by Plate I., where a large bending machine formerly driven by an engine having a cylinder 10 inches diameter with a stroke of 12 inches is now efficiently worked by a 3½ horse-power electric motor. The current for these motors is generated by a 50 horse-power Pieper dynamo driven by an ordinary horizontal engine, the steam being obtained from two Lancashire boilers which were already in use in connection with the steam driving of another portion of the works. Formerly the six engines in question were supplied with steam by two boilers, which are now dismantled, with the result of a net saving of 30 tons of coal per week and the entire labour in connection with stoking and upkeep. (See also Plate II.)

Another striking advantage is that the speed of the motors, being practically constant under all loads within their capacity, the machines driven by them are always running at the desired speed, and are therefore in a condition for producing the greatest possible amount of work. In reviewing this plant we have the advantage of ascertaining the approximate loss resulting from condensation in a long range of steam pipes, and the working of small high-pressure engines under conditions usually found in iron works and shipyards. It will be apparent, however, that the generation of power at one centre admits of an economy beyond this, viz., the use of a modern high-pressure triple-expansion condensing engine, with a consumption of 12 to 14 lbs. of steam per I.H.P. per hour, instead of a consumption of from 40 to 60 lbs., as frequently is the case at present. It is evident that the loss in such a case as that of Messrs. Dorman, Long, & Co. may be termed a maximum, on account of the machines working in the open air, and the steam pipes led underground, but the results from ordinary cases of shop machinery are often sufficiently startling to warrant more attention being given to them than they usually receive. For purposes of comparison we will consider the results obtained from two works of about equal driving power, one having an electric installation and the other steam.

One of the most complete installations of electrical driving in the world as applied to large industrial establishments is that of the National

Arms Factory at Liége, Belgium. These works were built in the 1889, and are of very large extent, employing 2,000 hands, the d output of finished rifles being 250. Some idea of the system adop and the value of machinery for economical and rapid production, r be formed when it is considered that there are about 58 parts i complete rifle and bayonet, involving in their production about operations; yet so great has been the development of machine tools u in this manufacture that, of the 750 total operations, only 6 per cent. performed by hand labour. Another feature is that a large percentag the machines are automatic, and advantage is taken of this by plac several in the charge of one operative. (See Plates III., IV., and V.

The whole of the machinery is driven by electric motors receiv their current from one central dynamo coupled direct to a Co condensing compound engine having two cylinders and indicating horse-power at 70 revolutions per minute, with a boiler pressure of 90

The auxiliary feed and condensing water is supplied by a pump dri by a 10 horse-power motor, receiving its current from the main genera dynamo, and placed on the canal bank 2,840 feet distant and 117 below the level of the engine.

The water after being used in the condenser is discharged into a t placed 40 feet high, from which it passes through finely perforated p in the form of spray into an open reservoir on the ground level, and this means is reduced in temperature so as to be again available condensing purposes.

The generating dynamo is placed between the high-pressure and l pressure engines, and the armature being on the main shaft, acts a fly-wheel. The armature which is 16 feet in diameter was constructed place. The electro magnets are twenty in number, and there are fo pairs of brushes, twenty on each side. The capacity of the dynamo 3,000 ampères at 125 volts and the makers guaranteed an efficiency 90 per cent.

The current from this powerful generator is distributed to about motors ranging from 3 to 50 horse-power, placed in different sections the works.

The machines used in the manufacture of rifles are necessarily of li design, consequently the motors are arranged to drive line shafting o and although the total length of main shafting exceeds 4,000 feet and total length of belting is about 11 miles, there are no indirect main dri a motor driving one line of shafting only, the object in view alw being the reduction of loss by friction.

Each motor is provided with an ammeter, and as those in charge know the amount of power required to drive the machines when being worked to their desired capacity, any increase of that power at once indicates that there is a waste in friction, whilst any decrease indicates that the machines are not doing sufficient work; and when it is remembered that the revolutions of the motor are practically constant under all loads within their capacity, it is impossible to imagine an arrangement which so exactly fulfils the requirements of maximum economical production.

Compare this with the wasteful arrangements so common in shipyards and engine works, where engines, often already fully loaded, have to drive still another new tool, and the "make-the-best-of-it" policy of giving just a little later cut-off is adopted. The result generally is that the mean revolutions of the main shaft are not only decreased by any variation in load, but are, in addition, highly sensitive to the variations of steam pressure. This is, however, a digression, and referring again to the Liége factory, there is also a 300 horse-power Willans engine, coupled direct to a dynamo, which generates the current necessary for recent extensions.

It has been found by careful experiment that the consumption of steam in the Corliss engine is about 14 lbs. per I.H.P. per hour, whilst the losses are 10 per cent. in engine friction, 10 per cent. in the dynamo, 2 per cent. in the conductors, and 15 per cent. in motors, or a total efficiency of 67 per cent. at the motor driving pulleys of the indicated power of the generating engine. The whole of the electric installation was made and fitted by the International Electrical Company of Liége from the designs and under the direct superintendence of Mr. H. Pieper, the managing director and electrician in chief of the company, and we have an ample testimony of the efficiency of the entire plant in the fact that, although the works have been running over three years and a half, there has not been one single stoppage of the main dynamo during working hours, and no accidents of any kind whatever.

Particulars such as these are always of general interest, but any radical change made in existing works involves a very considerable outlay, and extreme care is necessary to be certain that such a change would be commercially successful. It is therefore essential in the first instance to ascertain what are the conditions existing at present; so we will take as an example an average old-established marine engine works, of which there are many in this district, the majority of them having been added to year by year to meet the demands of trade, and where

extensions have generally been the result of a compromise between what was desired and what existing conditions would allow.

The works in question are steam driven, the boilers being arranged in one group, and supply steam at 60 lbs. pressure to 31 engines in different parts of the works. Eight of these are used for driving the machinery in the various sections of the works, and 23 are auxiliaries in connection with cranes, hydraulic pumps, and the like. The driving engines are of various powers and of designs which may be taken as representing a fair average of those used for the same purpose in similar works.

TABLE I.

Engine.	I.H.P.		Length of Steam Pipe in Feet.	Water Trapped in Lbs. per Hour.	Weight of Steam.				
					Calculated from Diagram.		20 %, for Cylinder Condensation.		Lbs. per I.H.P. per Hour, including Water Trapped.
	Loaded.	Light.			Lbs. per Hour.	Lbs. per I.H.P. per Hour.	Lbs. per Hour.	Lbs. per I.H.P. per Hour.	
No. 1	48	17·2	680	270	2,227	46·2	2,672	55·6	61
" 2	93·9	23·4	695	260	2,502	26·6	3,002	31·9	34·7*
" 3	44	20·2	833	190	2,365	53·7	2,838	64·5	68·9
" 4	28·9	15	969	130	1,562	54	1,874	64·9	69·3
" 5	56·2	20	511	110	1,890	33·6	2,268	40·4	42·2
" 6	75·7	22·8	971	27	2,580	34·1	3,096	40·9	41·4†
" 7	9·3	6·5	1,210	125	445	46·4	534	55·6	68·8
" 8	15·6	7·8	1,068	75	700	45	840	53·8	58·5

* I.H.P. with the dynamos not at work = 38·3.
† The small amount of water trapped here is due to the trap being placed very near to that of No 3 Engine.

No. 1 is a beam engine fifty years old, and is used for driving about 50 lathes, planing, slotting, and drilling machines of various sizes. With an average daily working load the I.H.P. is 48, whilst running the shafting only, and with the machines all standing it is 17. Steam is supplied through 680 feet of piping, and the water discharged from an automatic steam trap close to the engine stop-valve amounts to 270 lbs. per hour. The weight of steam used by the engine and as measured from the diagrams at the average daily load, viz., 48, is 2,227 lbs. per hour, to which should be added 20 per cent. for moisture in suspension, thus making a total, including the water condensed in the steam pipe, of 61 lbs. per I.H.P. per hour. No. 2 engine is a modern two-cylinder horizontal, with variable expansion gear worked by the governor. The machines driven consist of two dynamos for works lighting, as well as a large number of average sized tools.

It will be seen from the table that the average working load when driving the dynamos is 93·9 horse-power, but driving during the day the average horse-power is reduced to 38·3.

Nos. 3 and 4 are single cylinder inverted engines and afford a good example of the wasteful effects of overloading.

Nos. 5 and 6 are old-fashioned horizontal engines, in which the governor works an ordinary throttle valve, and both have been in use for about thirty years.

Nos. 7 and 8 are small inverted cylinder vertical engines running at 150 revolutions.

The wasteful effect of this system of driving is shown by the consumption of steam, which averages 50·9 lbs. per I.H.P. per hour, and to this has to be added the condensation in the steam pipes, which is 7 per cent., bringing the total up to about 55 lbs. per I.H.P. per hour, and even this is by no means exaggerated, as it is probable that the condensation in the pipes exceeds that indicated by the traps.

In comparing the two systems at this stage, and allowing 10 per cent. for engine friction in each case, and a total electric loss of 27 per cent. for dynamo conductors and motors, we require 45 lbs. of steam per effective horse-power at the main driving pulley of the steam installation against about 20 lbs. for the electric.

Taking the total at 500 effective horse-power (which allows 125 average for the 23 auxiliaries) in each case, and an evaporation of 8 lbs. of water per lb. of coal, the consumption of coal would be 36 tons per day for the steam and about 13 tons for the electric. In the steam installation under consideration the water is obtained from the water works main at considerable cost, whereas under similar conditions with a condensing engine the cost would be much less.

Another feature of value is the reduction of labour, which for stoking alone would be about one-half, whilst still further reduction could be made in the engine driving and greasing staff, as whilst steam engines require constant attention, the motors can be practically left to themselves except for starting and stopping, as should anything go wrong with any motor it would be immediately detected in the central station engine room by the indicator corresponding to the particular motor at fault. It will be evident that we have dealt with the greatest source of economy by the concentration in one highly efficient plant for the generation of power for the whole of the main driving of the machinery of the works. It will be interesting, however, to consider the relation between the power at the main driving pulleys and that absorbed by the machinery in doing actual work. Referring again to the driving engines 1 to 8 (Table II.) it will be seen that the loss in driving the shafting, belts, pulleys, etc., range from 25 per cent. to 70 per cent., or an average for the six engines of 43

TABLE II.

Engine.	Length of Shafting in Feet.	No. of Pulleys.	Length of Belts in Feet.	I.H.P.		Loss per Cent.
				Loaded.	Light.	
No. 1	370	153	4,292	48	17·2	35·8
" 2	782	113	2,263	93·9	23·4	25
" 3	515	283	3,582	44	20·2	46·2
" 4	571	335	4,881	28·9	15	52
" 5	691	79	1,401	56·2	20	35·6
" 6	381	22	464	75·7	22·8	30
" 7	117	49	1,210	9·3	6·5	69·9
" 8	242	70	1,429	15·6	7·8	50

per cent. These experiments have been confirmed by some made by Mr. Westgarth and referred to by him at a meeting of the Cleveland Institution of Engineers. Mr. Westgarth found that in an engine and boiler works he experimented on that of the total power developed by the steam engine 59 per cent. was absorbed by the shafting and gearing, and in one of the workshops where two long lines of shafting were used for driving a comparatively small number of machines the power absorbed was 75·6 per cent. of the total. In another workshop where the shafting was well laid and rope gearing used for the main drives the percentage was 42. The average of the whole experiments is therefore about 50 per cent., consequently it appears that half the mean power would be saved if all the machines could be driven by independent motors instead of by line shafting. This in an existing engine works is, of course, impossible, but there are many instances where long drives may be divided with great advantage, whilst the independent driving of large tools would be another very desirable feature.

An example of what may be termed ideal electrical driving is that of the Bedson Wire Company of Middlesbrough, where the installation is the most perfect and complete that has as yet been attempted in this country. Every process connected with the manufacture of wire is carried out by means of electricity, the wire drawing, galvanizing, spinning, and barb fencing machines, overhead and locomotive cranes, hydraulic pumps, induced draught fans, lathes, centrifugal pump, are all independently driven by electric motors. Owing to the entire absence of shafting and belting the construction of the building is very light, and the convenience of the whole plant is most noticeable. The current is generated by a 600 horse-power dynamo driven direct by a three crank triple condensing-engine with boilers of 160 lbs. pressure. (See Plate VI.) A special tunnel, 350 yards in length, has been constructed for the conveyance of the conductors, and branches are taken from these to the 50 motors which vary from 5 to 40

horse-power each. The lighting of the works is most complete, the greater part being carried out on the inverted arc principle, which is so perfect that there is an entire absence of shadows. The original plans for driving these works electrically were prepared by Mr. Selby Bigge, who appears to have given considerable attention to the question of electric driving. Before definitely deciding to put down such a novel plant several experiments were necessary, for which purpose special machines were designed by Mr. Bedson, the managing director of the Bedson Wire Company. These experiments were made at Liége by Mr. H. Pieper, and were so successful that after an exhaustive series of tests the directors of the company decided to adopt the electrical installation in its entirety.

A novel feature in connection with the boilers at Messrs. Bedson's works is the application of Messrs. Ellis & Eaves's well-known system of induced draught. (see Plate VII.) This is the second application of the system to land boilers, the first having been made at the Atlas Works, Sheffield, originally served by Lancashire boilers. These have gradually been replaced by ten single-ended boilers of the marine type, the advantages claimed being as follows:—

1. Considerable economy compared with the Lancashire boilers with Galloway tubes.
2. Considerable reduction in space occupied.
3. Absence of smoke.
4. Greater elasticity of power.

In ordinary work, by maintaining a vacuum of 3 inches at the fan, the combustion is at the rate of about 35 lbs. per square foot of grate surface, and one single-ended boiler can readily evaporate as much steam as three Lancashire boilers 27 feet by 7 feet, with ordinary chimney draught. Where the demand for steam varies in a works, the system is a great convenience, and this is especially the case for electric light installations. It is evident that with this system of draught, or with any other efficient system, the assumed consumption of 13 tons per day could be still further reduced.

From the comparison which I have made, we may fairly conclude that the saving gained by the substitution of electrical driving in an old-established works would be considerable. Whether this saving would justify the outlay in all cases would have to be settled by those who have their capital invested in works suitable for its adoption. I may say, however, with reference to the firm of which I am a member, that for some time we have had the matter under consideration, and the various

investigations and experiments made by Mr. D. B. Morison (some of which are enumerated in this address) have so convinced us of the commercial possibilities of the system that we have now on order a small plant prior to further developments hereafter.

I have endeavoured to confine myself in my remarks to a plain statement of what has been accomplished by making use of electrical power to drive machinery and have not gone into any of the possibilities the future may reveal.

We have known, however, the science of engineering to advance at times as it were by leaps and bounds, and from the rapid strides that this comparatively new energy has made within the last few years, we may have reasonable expectation of still further development in this direction.

In the address which I have given to you this evening, I feel that I have but inadequately fulfilled the task imposed when you conferred upon me the honour of electing me President of this valuable and widely known Institution, but hope that my remarks will be productive of help in the work before us. That the suggestion of the possibility of further expenditure of capital is unpalatable to many members of this Institution, I can well believe, seeing what dark clouds are hanging over us, but let us hope that, as in past times, the clouds will prove to have a silver lining and shortly disperse, giving place to pleasant sunshine in the shape of renewed commercial prosperity of which both capital and labour will receive their just and fair proportion.

Mr. William Boyd (Past-President) rose to propose a vote of thanks. He said it had been customary on such occasions to propose a vote of thanks to the President for the address he had delivered at the opening of the session. There had been five such addresses delivered to the Institution, and he ventured to think that none of the series would have more interest to the members or be more valuable than the one they had just listened to. It was a great advantage when a President could strike out a line of his own, and endeavour to leave his mark on the annals and records of the Institution. He could not help feeling personally very great interest in the address that had been delivered that night, because it followed on the lines which he ventured to lay down some years ago as those in which that Institution could profitably follow, he meant what might be summed up in the words "economy of production." That meant a great deal to any of those gentlemen who were interested in the industrial enterprises in this part of the world, and, if he might be allowed to say so, was a subject which had hardly received that attention during the last ten years

from the members of that Institution which might have been given to it. He was quite aware that papers on the stability of ships, of which he knew nothing at all, were the means of producing very interesting discussions, but as the large majority of the members, putting aside a very small minority, were all interested and were engaged and occupied in different industrial establishments, the economical working of these establishments was of the greatest interest to all of them. He would again venture to suggest that the impetus which had been given by the address of Mr. Richardson might be very profitably pursued by the members, and particularly the younger members of the Institution. Investigations might be carried on with success by men who were actually engaged in the works themselves, whether shipyards or engineering works, and it did not necessarily require a very high scientific or mathematical knowledge, but mainly a careful observation and a noting of the results that occurred under varying conditions. He thought more economy might be achieved and great advantage derived to all of them interested in the shipbuilding and engineering trades of this district if such investigations were pursued. The address read that night would, he hoped, be productive of a discussion on some of its details. He did not propose to detain them by remarks on that point, but he was quite sure they would join him in thanking the President for his address. Before he sat down, and by way of giving a start to the technical discussion which was to follow, he should like to ask this question—the address had given the record of the power of the engines when driving the machinery and gearing light and loaded, and a considerable saving was claimed for the electrically driven system on the ground that 50 per cent. of loss might be saved. It appeared to him that that was rather sanguine. A considerable portion of the loaded running power would be the gearing of the machines themselves. With the electric engine driving a heavy lathe the gearing would still be employed as at present. That was a point which amongst others would, no doubt, be alluded to in the discussion. There was another point in the paper, and that was the question of the condensing engines. There was no doubt that high-pressure engines exhausting into the air was a most wasteful arrangement, but there was very great difficulty in applying a condensing system unless they had a very suitable and handy supply of water at a cheap cost. It was very difficult to apply condensing engines to ordinary shop driving purposes, and, therefore, the triple-expansion condensing engine which Mr. Richardson had taken as a basis presupposed a condition which was not always easy of accomplishment. Before sitting down he would like to remind some of the members present that it was within ten years of that day

that the first meeting of the Institution was held in that room, and he only hoped it would have many more prosperous decades before it.

Mr. ROBERT THOMPSON (Past-President), Sunderland, seconded. He said he was sure they had listened with very great interest to the opening address of the President. As Mr. Boyd had pointed out to them there were two or three features about it that were specially interesting. With respect to the remarks of Mr. Boyd as to that Institution being ten years old, those of them who remembered the Presidential address given by Mr. Boyd would probably remember the various points sketched out in that address, and their President's address that night was a complete fulfilment of the plan sketched out by Mr. Boyd in his address so far as practical shipbuilding and engineering were concerned. At the present time his firm were just contemplating a step in the direction of the President's suggestions. There was nothing so attractive in science as electrical engineering, and he had no doubt the result of the address that night would lead to the further investigation and development of electricity. They as shipbuilders, as well as engineers, would be benefited by it. If they had no trade, then science would be no use, but it was owing to the help that science gave that they were enabled in those times to make business successful. The President's address that night would assist them to maintain profitable undertakings being carried on on the North-East Coast. He was not afraid of the future. He was quite sure their President would have reason to remember his speech that night from the results which would accrue from it. It reflected great credit on the original promoters of that Institution that they should have as President alternatively a shipbuilder and engineer. They had always had a change. It was a feature of the times, and it was fortunate that the Institution had as President an engineer at the present time when so many engineering matters were ripe for discussion. He had great pleasure in seconding the vote of thanks.

The PRESIDENT here said that he would leave to the meeting to decide whether the paper should be discussed or not. What he would suggest was, that the vote of thanks on his address should be passed, and then they might open the discussion on the paper, which might be adjourned to their next meeting at West Hartlepool. He saw many gentlemen present who might add to the facts and corroborate some of the remarks he had made.

Mr. W. BOYD (Past-President) having put the motion to the meeting it was carried by acclamation, and it was then agreed to open a discussion upon the address.

DISCUSSION.

Mr. F. C. MARSHALL said he thought it would be a pity to allow that meeting to separate without, to some extent, discussing the subjects the President had suggested in his paper. It seemed to him that there were several gentlemen there who might not possibly be at Hartlepool, and it would be well if they could pursue the discussion to the limits of the time allowed. He thanked the President very heartily for the very suggestive paper which he had read that evening. Their friend Mr. Boyd had said that presidential addresses were of three kinds—the historical, the practical, and the suggestive. They had had a very suggestive address from the President, and they were very much obliged to him for it. There was nothing that should stimulate the younger members of the Institution more than such an address, they had in it sufficient practical suggestions to induce them to investigate for themselves. As Mr. Boyd had said that did not require very much skill to do. It could be carried out in the ordinary occupations in their engine works and shipyards. There was one thing in the development of electricity in Newcastle, which was a very instructive corollary to what the President had said that night. The Electric Light Company, which occupied part of the old classic works of Hawthorn, commenced their operations some two or three years ago, and had laid down their plant and worked for two years, with the result that they consumed a certain amount of coal. They put down at once a condensing engine giving the same amount of light, and they are doing their work now with exactly one half the amount of coal. That was an experience very much confirming the President's views that night. As to the waste of electric power, his friend Mr. Wigham Richardson had suggested that somebody should mention that there was always a source of electric power at the bottom of coal mines in the accumulation of water, provided that they could get an outflow at the bottom of it. The idea of the President's paper was really suggestive, and he would say to the younger members in particular, for they had the world before them, it was of the utmost importance that they should take heed to such suggestions as they had heard that night to produce and carry on work more cheaply.

Mr. T. WESTGARTH said that as a Middlesbrough member of the Institution, he would like to add his thanks to the President for his address. It was evident that an immense amount of trouble had been

taken in gathering together the information by the President, who had not only pointed out difficulties with which we had to deal, but had suggested the means by which these difficulties could be overcome. Mr. Boyd asked what the figures given by the President as to the power consumed in driving shafting represented. So far as the figures ascertained by the speaker, which were quoted by the President were concerned, the engines were indicated with all the shafting running upon the loose pulleys, so that everything was included except the power required to drive the machines. Mr. Boyd remarked that he saw difficuities as to adapting the President's suggestion to use condensing engines for driving the works' shafting. The speaker had come across the same difficulty, and had overcome it by the use of the evaporative surface condenser, which could be worked with less water than was used by an ordinary high-pressure engine. He did not think it was generally appreciated by shipbuilders, engineers, and others, what a large percentage of power used in their works was lost in transmission, and it was the consideration of this subject which led him to investigate the matter. The electrical transmission of power was not only the means of saving a great deal of the loss by transmission, but made it possible for the steam user to generate the whole of his power by high class economical engines, which appears to be one of the chief advantages of the system. The President mentioned a case where 36 tons of coal was now being used per day, which he anticipates might be reduced to 13 tons per day by substituting a new central generating plant and transmitting the power electrically. It appeared to the speaker that the President had understated the case, because his figures showed that in the works referred to the engines were using about 60 lbs. of steam per horse-power per hour. There would be no difficulty in producing the power upon a quarter of this weight of steam by the use of high-pressure boilers and triple expansion engines, so that apparently the quantity of coal could be reduced from 36 to 9 tons. One of the most important matters to be considered in connection with the electrical transmission of power was, of course, the cost of carrying out the installation. The speaker had gone into this matter very carefully, in conjunction with Mr. Selby Bigge, and had found that in an ordinary shipyard or engine works the whole of the machinery, engines, boilers, etc., might be cleared away, and new engines with high-pressure boilers, dynamo, motors, and fittings, substituted for doing the work, and the cost would be paid for by the savings of fuel, water, and other expenses, in less than four years.

Mr. J. PRICE—Does Mr. Westgarth include the cost of fitting motors to the machines, such as punching machines, etc., in position ?

Mr. WESTGARTH replied that in making the calculations they had included the cost of separate motors for the detached machines, such as punching presses, etc., about a shipyard, and also for the larger machines in the works, such as wall planing machines, etc., in the engine works, and the application of separate motors to the cranes, and to the lines of shafting for smaller machines. He was glad to observe that the President recommended the use of the ordinary triple-expansion engine for driving the dynamo for large power installations. He was quite satisfied that for larger powers the wisest course would be to adopt the ordinary marine type of triple-expansion engine, which has done such good service for the engineers of this district. As the maker of the engines and boilers for the Bedson plant mentioned by the President, he might state, and he thought it would interest the meeting to know, that the installation promised to be very successful. So far only preliminary trials had been made, but they had given complete satisfaction to those concerned.

Mr. J. P. BEDSON thanked them for the opportunity of being present at the President's address, and for their invitation to be there that night. As he was a total stranger he must ask for their indulgence. He was a Lancashire engineer, and came to the North-East Coast full of Lancashire prejudice, but he had come to the conclusion, after looking into marine engine practice there that the wonderful efficiency they had obtained he had concluded in putting down an installation for his company of the inverted triple-expansion steam engine, such as was used at sea, and which had given such good results at sea, hoping for a repetition on land. He was led on into electricity. He went into the matter full of a mechanical engineer's prejudices, and pooh-poohed the idea throughout, but when he visited works on the Continent and saw what they were doing—and which quite corroborated the results given by their President in the consumption of coal and the economies in driving machinery—he changed his mind. In one case, he understood, where the steam plant, mechanically driven machinery, consumed 3,000 kilos. of coal in doing a certain work, the mechanical transmission was taken out and electrical transmission put on, and the work was done for 800 kilos. of coal. That would bear out Mr. Westgarth's results. The National Arms Factory of Liége were producing a rifle in ten hours on a consumption of 1½ horse-power by electricity, as against 3½ horse-power in the mechanical transmission factories iden-

ed. These figures appealed very strongly to him, and he
lly into the matter, and considered it very seriously.
a bridge yard in Germany where steel and iron bridges were
n had been driven for two or three years almost entirely by
, and judging from the economies in the adoption of electricity,
ey were going to hold their own, they would either have to adopt
y in shipyards or be driven into it, or trade would be taken away
em. They (Messrs. Bedson) had not yet got their plant to work,
e trials had been exceedingly satisfactory. As an instance of the
nience of electricity, he had taken the liberty to borrow a current
his neighbour by tapping their main. Fortunately, his neighbou
in for a small electrical installation of 50 horse-power, and his wire
e near their place, and they connected them. He had been able t
minate the whole length of his shops with incandescent lamps, as we
to do the work, and also to drive a travelling crane and jib cran
With regard to the experiments that they had made, he might say that
was an oversight that the mention of a Newcastle firm had not been ma
in the President's paper, for through the kindness of Messrs. Scott
Mountain they were enabled to carry out some experiments at their sh
There was one point about electrical transmission to bear in mind, and t
was to do all the driving they possibly could with individual motors
each machine. There was where a great economy would be found.
had even gone so far as to believe that in cotton mills there would
electrical power so divided that the spindles could almost be driven sing
and individually by little motors for each spindle.

Mr. D. Selby Bigge said that there was one point he would like t
mention in connection with losses arising from the transmission of pow
through long lines of shafting and belting, or through other forms
gearing. The point he wished to draw their attention to was, perh
what might be termed a fine one, but still it was too important
entirely neglected. What he referred to was the loaded frictional l
against the light frictional loss. There was often a considerable
ence between the two, as the frictional loss rapidly increased in pro
to the load on the shafting, whereas when the shafting was runni
the friction was considerably less. When speaking of friction
works, it was generally understood to mean that indicator diag
taken when all the shafting was running with the belts on the l
of the various machines. This was correct as far as it w
ence between the light and loaded frictional loss shou

It would thus be seen that with mechanical forms of power transmission the frictional loss increased with the load, and was not a constant. With purely electrical transmission, that is to say, in the case of works driven by self-contained electric machine tools, these frictional losses were entirely eliminated, and the loss in transmission through the cables should not exceed 2 or 3 per cent., assuming engine friction to be the same in either case. The speaker said that he was now having some careful tests carried out in a Lancashire cotton mill on the loaded frictional loss, and hoped shortly to be in a position to publish the results; he would, however, be glad to hear if any of those gentlemen present had carried out any experiments in this direction. As regarded the general application of electric driving to works, the main feature lay in the fact that it was possible to concentrate in one highly efficient plant the generating power for the whole place, this power was cheaply generated, easily and efficiently transmitted, while the control for economical running was perfect. There were many points in connection with the convenience and simplicity of electric driving which did not appear to engineers at first sight, but they soon became evident in practical work. There was undoubtedly a large scope in shipyards for the application of electricity, and the speaker considered that many developments in labour-saving electrical machine tools would take place at those yards where electric power was available. As he had so often stated his views on the subject in papers which he had read on electric power work as to the pros and cons of the system, he would not detain them further at that late hour, as other gentlemen would, doubtless, like to join in the discussion.

Mr. W. H. PANTON said they had a small application of electricity and they had found a very great saving. They had only spent a few hundred pounds; from the saving already effected they expected to get this back in a year. He thought the statement of Mr. Westgarth about getting the value back in four years was very much within the mark.

Mr. L. NEWITT said he regretted that he was unable to hear the reading of the President's paper and the early discussion upon it, but hoped to read in the *Transactions* all that had occurred. He had had some experience with electric motors, and he would like to put before them a few points which had been noted. The general use of the electric motor appeared to be advocated more by those who use them than by electric engineers. This may be explained in that they are (as compared with the

ordinary steam engine and its boiler):—(1) Clean; (2) less nois (3) take up less room; (4) and are more readily applied to many classes machines and shops. However, before adoption, the efficiency of the mot system should be carefully balanced against the ordinary belting a shafting. They had heard that night about certain works and machir being driven by electric motors, and again that each machine was bei driven by its own motor. That, however, seemed even to an electric engineer to be rather a big stride. If they took the case of an ordina works on the Tyne having an engine of 250 horse-power situated not f from the various sections of shafting from which all the machinery w driven, the efficiency of this system throughout would, in all probabili be at least 75 per cent. If more, the shafting, owing to heating and oth causes, would either break down, or the engineer in charge would so discover the defects and remedy them. Whereas if motors were used f this work the losses due to the dynamos, the cables, and then reconverti this electric energy back again by the use of the electric motor, its sha ing and reducing gear necessary to reduce the speed (which usually wh running efficiently is about 600 revolutions) for the various requireme the system would work out exceedingly well if anything like 50 per ce could be got. These remarks applied only to the ordinary compact engine ing works. When a works had been so laid out as to require special stea piping to be led to auxiliary engines and machines at a distance of s 100 yards, then the field for the motor commenced, and, as clearly poin out in the President's valuable address, the statistics at once sho the advantages of electrical transmission as compared with the run of steam pipes to a distance from the boiler, owing to condensation other causes. This appeared to be the correct field for motors, an in a works where the machines and main shafting were close to the engine. Here it was hardly possible to compete to advantage ordinary shafting and belts, but when extensions were carried out th for each case the question of electric motors came in for conside Also there was no doubt as to their being of great value for the of dock gates and out-door crane work, where the cables could easily led than steam pipes. For mill work motors to each might be considered advisable, because transmission of power by supposed to have often caused fire, and again in mines the mo found a safe home for many purposes. In ships the motor tageously used for fans and the like to avoid running long steam piping. In the construction of ships, motors had bee drilling and other work, where the motor had to be contin

He had tried a motor for doing drilling work, but it was not a great success. It was found that it required two men to lift it about, and the delay caused by moving it from one hole to another was such as to make its work equal to that of only two good drillers. The question of superintendence must not be overlooked. They saw continually failure after failure arising, and these could in most cases be traced to the incompetence of those put in charge of electrical machinery, and it was good at a meeting like this to bring before them the importance of having properly qualified men in charge who knew how to avoid the diseases to which electrical machines are subject. He had been most interested in what he had seen in the President's paper, and had no doubt it would be of great value to the Institution.

On the motion of Mr. W. C. MOUNTAIN the discussion was adjourned.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

ELEVENTH SESSION, 1894-95.

PROCEEDINGS.

SECOND GENERAL MEETING OF THE SESSION. HELD IN THE ATHENÆUM, WEST HARTLEPOOL, ON SATURDAY EVENING, NOVEMBER 17TH 1894.

ALDERMAN THOMAS RICHARDSON, B.A., J.P., PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the Eleventh Annual Meeting held in Newcastle-on-Tyne, on October 16th, 1894, which were approved by the members present, and signed by the President.

The ballot for new members having been taken. the President appointed Messrs. C. D. Doxford and G. W. Sivewright to examine the voting papers, and the following gentlemen were declared elected :—

MEMBERS.

Bigge, D. L. Selby, Electrical Engineer, 27, Mosley Street, Newcastle-upon-Tyne.

Duncan, George Thomas, Engineer, c/o Messrs. Tangyes, Limited, 3, St. Nicholas' Buildings, Newcastle-upon-Tyne.

Elliott, William D., Consulting Engineer, Hessle, Hull.

Graham, William, Engineer, Primrose Villa, Kingsland Crescent, Barry Docks, South Wales.

Green, Frederick W., Marine Engineer, 14, Monk Street, Sunderland.

Houston, John, Supt. Engineer, 32, Randolph Street, Sunderland.

Jack, William C., Supt. Engineer, Service Subverstionnes des Correspondances Fluviales au Tonkin, Haiphong, China.

Stroughair, John W. H., Engineer, Whitewell Lane, Ryton-upon-Tyne.

MEMBER (LATE GRADUATE).

Finch, Herbert K., Colliery Agent. c/o Messrs. Blainscough Colliery Co., Coppull, near Chorley, Lancashire.

ASSOCIATE.

Ball, Alfred F., District Representive of Messrs. Siemens Bros., London, 14, Lansdowne Terrace, Gosforth, Newcastle-upon-Tyne.

GRADUATES.

Cairns, Charles W., Apprentice Engineer, 84, Addison Road, Heaton, Newcastle-upon-Tyne.

Hudson, Charles J., Engineering Student, 84, Addison Road, Heaton, Newcastle-upon-Tyne.

Mace, Charles, Apprentice Engineer, 253, Albert Road, Jarrow-upon-Tyne.

Thomas, Robert Gates, Apprentice Engineer, 17, Denmark Street, Gateshead-upon-Tyne.

The discussion on the President's Inaugural Address was resumed.

Mr. ANDREW YOUNG read a paper on "A Brief Outline of the Theory of the Rolling of Ships.

ADJOURNED DISCUSSION ON THE PRESIDENT'S INAUGURAL ADDRESS.

Mr. W. C. MOUNTAIN (Newcastle), resuming the discussion, said he had read and listened with very considerable interest to the President's address, and he considered, as an electrical engineer, that a very important subject had been brought before the Institution. Until Prof. Kennedy as President of the Institution of Mechanical Engineers took up electrical matters in connection with an engineering institution he was rather afraid that electrical engineers were looked upon by the members of the general engineering profession as quite insignificant people, and it was therefore all the more gratifying that a gentleman holding the position of their President should think it worth his while to take so much interest in electrical matters. There was no doubt that the President had touched upon one of the most important applications of electricity in his address, viz., its application to motive power purposes, and he hoped he should not be saying anything in any way detrimental in suggesting that their President might have looked nearer home for examples of successful applications of electricity, *i.e.*, driving workshops and such like work, instead of going to Belgium for it. Being an Englishman he had a very strong feeling that they should try to support their own country ; and he could unhesitatingly state that there was first of all no need to go abroad for successful applications of electricity to almost any purpose, nor was there any need to go to Belgium, Germany, nor any other country to purchase first class dynamos and motors ; and he would go further and state that in point of general excellence, both in design and workmanship, there were a large number of electrical engineering firms in England who were capable of, and did at any rate, as good work as any of the foreigners. The installation of electric transmission of power referred to by their President at the Small Arms Factory at Liége was particularly interesting, and he should be glad if he would give the Institution some reliable information as to the comparative cost per unit of current generated by the Corliss type of engine and by the Willans vertical engine and dynamo coupled. For his own part he had yet to see where the advantage came in, in turning the fly-wheel of the engine into the

dynamo; it might be that it made a better arrangement; but in point of first cost, which was a point that had to be seriously considered, he was under the impression that a coupled engine and dynamo of the Willans or other high speed type, or of a Corliss engine or other horizontal engine of an economical type driving by ropes or belts on to a higher speeded dynamo would not only be just as efficient but a much less expensive type of plant. Their President had touched on an extremely important matter when he mentioned in his paper that at the Liége factory the electric motors drove on to lines of shafting instead of a separate motor being attached to each machine. He thought there was no doubt that in an ordinary engineering works the most economical arrangement both regards first cost and also efficiency where a large number of tools were required would be obtained by adopting the system where an electric motor was put down, say in each shop, and driven by belt or otherwise or to its line of shaft and from this shaft power was transmitted to the various machines. Thinking that a rough comparative estimate of (1) the prime cost of complete electric transmission systems by large and small motors and (2) the total efficiency of these systems might be of interest he had prepared two rough estimates, and had assumed in each case that the indicated horse-power of the engine was 200, and he had taken the President's figures as regarded the efficiency in the No. 1 estimate, which was for a plant consisting of engine and dynamo with four electric motors of 33½ effective horse-power each. In the No. 2 estimate he took the same value of power for the engine and main dynamo, but he had taken a number of smaller motors and assumed that one motor drives one machine. In the No. 1 estimate there was a total of 114 effective horse-power available for driving the four lines of shafting, and in the No. 2 estimate only small motors were used with the same watts or electrical output at the terminals of the motors. They were only able on account of the lower efficiency of small motors to obtain 90 effective horse-power. It would be noted that the 100 effective horse-power is made up as under:—

2	motors of	5	horse-power	...	...	...	= 10
10	„	3	„	...	...	...	= 30
10	„	2	„	...	...	...	= 20
30	„	1	„	...	...	...	= 30
20	„	½	„	...	...	...	= 10
							100

This being what he roughly considered the number of machines approximately required for any engineering works where 90 horse-power was required for driving tools. The comparative cost of the two schemes worked out as under :—

No. 1 Estimate.

Installation with four motors driving on to four main lines of shafting.

	£
Cost of horizontal engine, with Corliss gear, capable of developing 200 indicated horse-power	670
Dynamo to give output of 120,000 watts, together with switchboard	750
Conducting cables between dynamo and the four main motors, say	200
Four electric motors of 33½ effective horse-power, each £220 ...	880
Erection, say	200
Total	£2,700

No. 2 Estimate.

For installation with independent motors driving each machine.

	£
Cost of horizontal engine, as per No. 1 estimate ...	670
Dynamo and switchboard, " " ...	750
Cables for 70 motors, say	700
2 5 horse-power electric motors, each £60	120
10 3 " " " £50	500
10 2 " " " £35	350
30 1 " " " £25	750
20 ½ " " " £15	300
Erection, say	500
Total	£4,640

The above showed a saving of £1,940 in favour of the No. 1 estimate. The next point, one which was extremely important, viz., was that of efficiency. Comparing No. 1 estimate with No. 2 estimate, and assuming that in both of them the same type of engine was used and the same dynamo, they had available the indicated horse-power of the engine, and deducting 10 per cent. at the dynamo terminals an output of 120,000 watts. Taking the loss of the engine as 10 per cent. and in the dynamo 10 per cent., he considered the loss of 2 per cent. mentioned was too small to cover leakages in cables and other contingencies, and he had therefore assumed 5 per cent. as being nearer the figure in actual practice. Deducting 5 per cent. from the watts at the dynamo terminals, viz., 120,000, left 114,000 watts at

the motor terminals. Assuming large motors were used, viz., of 33½ effective horse-power, the efficiency should be fully 88 per cent., and therefore with motors at this efficiency it was possible to obtain 134 effective horse-power on the motor shaft, *i.e.*, four motors of 33½ horse-power each, this equalled an efficiency of 67 per cent. at the motor shaft; but assuming that the four lines of shafting absorbed 5 horse-power, it left 28½ horse-power available for driving tools, and therefore the total efficiency at the tools equalled 114 horse-power, or 57 per cent. of the indicated horse-power of the engine. Taking the other scheme, *i.e.*, separate motors to each machine, and taking the efficiency of the motors as under :—

2	motors of	5	horse-power	=	10	horse-power	=	80	per cent. efficiency.
10	,,	3	,,	=	30	,,	=	75	,, ,,
10	,,	2	,,	=	20	,,	=	66	,, ,,
30	,,	1	,,	=	30	,,	=	60	,, ,,
20	,,	½	,,	=	10	,,	=	60	,, ,,

gave a total power at the motors of 100 horse-power, but adding on the loss due to the lower efficiency, in accordance with the efficiency stated above, would necessitate an output equal to 113,000 watts at the motor terminals, or, say, practically 114,000 watts, to compare with the other estimate. Therefore the resulting efficiency was only equal to 50 per cent. of the indicated horse-power of the engine, against 57 per cent. in the other scheme. In addition to the loss of the small motors must be taken additional loss due to transmitting the power from a high speed motor to a slow speed machine, which could not be at less than 10 to 15 per cent., therefore the all-round efficiency of the four large motors will be very greatly in excess of the powers to be obtained from the small motors. It was very gratifying to see such satisfactory results from the electric installations at Messrs. Dorman, Long, & Co.'s works, but he was satisfied similar results could be obtained in very many of the shipyards and similar works on this coast. He thought the Institution would be interested in having some further particulars as to the class of engine used and the method of laying the mains and distributing the current to the various motors, and he would ask Mr. Panton or Mr. Bigge to supply these. It would also be particularly interesting to know the system of distribution that had been adopted at the Bedson Wire Works particularly, as wire-drawing was an operation which presents some considerable difficulties. In the first place a number of small motors would, of course, run at a high speed, and a description of the type of reduction gear would be of great value and further the margin that has been allowed between

the actual horse-power required for wire-drawing and the horse-power which the motor was capable of giving in emergency, as, of course, a very heavy pull was required to start wire-drawing, and he would therefore like to know whether it had been decided to put down a separate motor to each block, which he understood was the original intention, or whether one motor had been put down to drive a number of blocks. With regard to electric transmission installations in this country compared with abroad, he noted in the electrical papers Messrs. Siemens Bros. had in their works what he believed to be one of the largest installations in any works in the world, and considerably larger than the Liége plant. Their installation consisted of one Bellis engine, with cylinders 15 by 23 by 10 inches, running 350 revolutions, and developing 300 horse-power; three Willans engines, 14 by 20 by 9 inches, running 350 revolutions, and developing 300 horse-power, or collectively 1,200 horse-power; 3 boilers of 400 horse-power each; 4 dynamos, each giving an output of 2,000 ampères, 120 volts, or collectively 960,000 watts; 13 40 horse-power motors, 520 horse-power; 7 20 horse-power motors, 140 horse-power; 2 15 horse-power motors, 30 horse-power; 8 10 horse-power moters, 80 horse-power; 24 10 to ½ horse-power motors, say 5 horse-power average, 120 horse-power; total, 890 horse-power. They had only to look a little further and they found the very extensive application of electricity at the Liverpool and also the London Electric Tramways. In their own works, to which he would for a moment refer, they originally had a Lancashire boiler, 26 feet by 6 feet, a Ruston Proctor portable engine, developing 50 horse-power, and a vertical boiler of 20 indicated horse-power. These boilers steamed the engine in the machine shop, erecting shop, and the electrical shop. As this machinery occupied valuable space, viz., 90 feet long by 45 feet wide, and the coal consumption was 25 tons per week, and they required more room for extending their premises, he decided to take out the boilers and engine and to put down an electrical plant in the yard, which consists of 2 locomotive boilers, capable of giving collectively 160 horse-power, at 150 pounds steam pressure; a vertical compound engine, 10 by 18 by 10, running at 250 revolutions, and developing 100 indicated horse-power. From this plant they were driving a dynamo giving an output of between 40,000 to 50,000 watts, and driving motors as follows:—1 motor in pattern shop, 15 horse-power; 1 motor in erecting shop, 15 horse-power; 1 motor in foundry, 12 horse-power; 1 motor in tool shop, 2 horse-power; 1 motor in armature testing shop, 4 horse-power; 1 motor for 2 saws, 2 horse-power; 1 motor for fan for tinsmith, 1 horse-power. The engine in the machine shop being still driven by

steam from the boilers. The result of this had been that they were able to erect a new winding shop, 90 feet long by 45 feet wide, in the works, where rent was very heavy, and they could not do less than credit £150 per annum towards this shop. In addition to this they were saving 14 tons of coal per week, and two men attending to the machinery, and this saving had been effected after doubling the size of their works. Therefore they could not at the very least estimate the saving at less than £700 per annum. Another important installation in this district, and one which would compare favourably with any other, was a plant which his firm had just erected at the Cowpen Coal Company's Colliery at Cambois. The pumping underground was originally done by the haulage engine driving the endless wire rope, the rope passing over the pulleys of these pumps underground and driving them, the pumps being 8 inches diameter by 18 inches stroke. The plant which his firm had erected consisted of a Corliss type engine driving on to a dynamo, giving an output of 50 units; the current is taken underground and distributed to 7 pumps, each pump being driven by an electric motor capable of developing 8 effective horse-power, and driving through worm gearing on to a crank disc, to which the connecting rod of the existing pumps was coupled. The following were the particulars of the old and new plants:—

Old Plant.—Size of engine used for driving the haulage rope and the power used for the pumping:—Two engines, each having a pair of cylinders, 14 inches diameter by 14 inch stroke; one engine with pair of cylinders 12 inches diameter by 14 inch stroke; three locomotive boilers, *i.e.*, a boiler to each engine, the boilers being 3 feet 8 inches diameter, with barrel 8 feet long, fire-box 5 feet 9 inches, each boiler being fitted with 39 tubes 3 inches diameter. Coal consumption for pumping work per week about 30 tons. Total number of men employed for stoking and driving engine on the main roads, also attending to the ropes, 5 men and 4 boys. Total cost per annum for the old system of driving, £1,950.

New Plant.—One engine with Corliss type trip gear, with cylinder 13½ inches diameter by 30 inch stroke single cylinder. One boiler of the locomotive type the same size as the three boilers originally used, *i.e.*, 3 feet 8 inches by 8 feet barrel, 5 feet 9 inches diameter for fire-box, fitted with 39 tubes 3 inches diameter. Coal consumption 9 tons per week. He might here mention that the coal consumption of 9 tons had been the consumption during the time that a large quantity of standing water had been got out, and the plant had been working much longer hours than the old plant had done. The number of men now employed to attend to the engine and boiler and 7 pumps was 3 men and 2 boys. Messrs.

Forster anticipated from figures which they had before them that the annual saving would be not less than £1,000. With regard to the results at Cambois Colliery, it was only fair to Messrs. G. B. & T. E. Forster, the managing owners, to explain that the original system of pumping was not specially designed for the colliery. It was necessary to pump a small quantity of water, and one pump was put down; further pumps were then added as the water increased. At the same time this represents very fairly the existing system of pumping in a large number of collieries in this country, and clearly shows the economy which might be anticipated by adopting the system elsewhere. Since the paper was read he had also had an opportunity of hearing the discussion which had so far taken place, and it was extremely gratifying to him to think that so many prominent men had come forward and expressed their practical views on the system of electric transmission. Mr. Wm. Boyd had probably mentioned one of the most important items in the whole system, and that was the question of reducing the high speed of an electric motor down to the lower speed required for machine tools and various operations. There are many systems of reduction:—1st, by means of pulleys and driving belts; 2nd, by means of spur gearing; 3rd, by worm gearing; but whichever of these systems was adopted there was bound to be a loss, and this loss was greater than was fully appreciated. He had applied different systems of reduction gear, and he was inclined to favour a combination of gearing and belting, although he had been very successful in the application of worm gear to pumping machinery, but he thought they should not estimate on a loss much less than 15 per cent. Mr. Westgarth had very properly brought forward the triple expansion type of marine engine as a suitable motor for driving electrical machinery, and there was no doubt that this type of engine was eminently suited for the work. It would, however, be necessary, with a triple expansion engine, to provide that the load was more or less constant. Of course in installations, such as lighting plant, where the load was very varying, a triple expansion engine would not, he considered, have as high an efficiency, *i.e.*, an all-round efficiency as a compound engine, because during the hours of light load the engine would be doing little or no work, and the low pressure cylinder would be a drag instead of a help, but for driving installations where motors were used, and the load was practically constant, there was no doubt that the triple expansion engine, with a steam pressure of 160 lbs. per square inch fitted with a condenser was a most economical and satisfactory type of engine. Mr. Westgarth had, however, in his opinion gone much too far in the statement he had made respecting the ultimate saving by putting down

electric plant. He was quite sure Mr. Westgarth did not intend to make any statement that was not perfectly accurate, but he thought that general statements such as he made in stating that the total cost of the plant would be saved in less than four years was one that should be more carefully explained. Without wishing for a single moment to depreciate the value of electric motors or electric transmission, he thought it behoved every electrical engineer, who at any rate had sufficient engineering knowledge, to be careful in guiding his customers instead of misleading them. It was absurd to suppose as a general fact that all they had to do was to put down a dynamo and a motor, and connect it with cables, and an economy resulted. Yet this appeared to be the practice which was being preached by some of the electrical engineers of the present day. He was perfectly convinced that where a really high-class Corliss or triple expansion engine could be put down, and the power could be transmitted by ropes direct on to lines of shafting, and the shafting was erected in a thoroughly economical and perfect manner, that the shafting could be driven at less loss than would exist in a transmission plant where the power had first to be turned into electricity, passed through cables, and finally turned into power again. This, according to figures given by the President, meant a loss of 27 per cent. He (Mr. Mountain) would say nearer 30 per cent. He thought most engineers would agree with him a loss of 30 per cent. did not exist in transmission by ropes—in fact, by recent tests he had made he had found that the loss was only 3 per cent. He mentioned these facts simply because he thought it was their duty to persuade their customers to put in what was really the most satisfactory and economical system rather than have electrical plant simply because they happened to be makers of it. On the other hand, where a number of machines or shops distributed over a certain area had to be driven, there was no doubt that the electrical system with independent motors for each shop, or probably for each machine, was a most economical plant, and this could not be better proved than by the results obtained by Messrs. Dorman, Long, & Co. in their own works, and by his firm in their engineering works. Mr. Selby Bigge had raised a point which was certainly an interesting one, but was somewhat simply answered. He asked what was the difference between loaded loss and light load loss? He must be perfectly aware that, assuming he was driving shafting, the friction was necessarily somewhat greater when it was loaded, but he must also be aware that the friction was equally increased if he had reduction gear between the dynamo and the machine he was driving, so that he did not think any very great point could be made of this. Mr. Newitt did not

speak in a very hopeful manner as regarded the application of motors to ship work, but he thought Mr. Newitt would probably change his mind, as there was no doubt that, for driving fans and also for driving auxiliary machinery on board ships, there was a very great future for electrical work. His firm had recently supplied electrically driven fans for induced draught. These fans were exceedingly compact, and as the motor could be run at a high speed without vibration, a much smaller fan could be used than with steam engine driving. He regretted he had taken up so much of their time in the remarks he had made, but he hoped that all members who were in any way interested in this system of driving, which would undoubtedly be one of the most important branches of engineering in the future, would not be backward in saying what they could either for or against the system.

Mr. Joseph Adamson (of Hyde) said he must express a feeling of obligation to the President of the Institution for having brought the subject of electrical transmission of power before the engineers of the North-East Coast. In their own shop they had given considerable attention to the driving of their tools since 1888, and he did not see that there was any great difference between a Lancashire boiler works and other branches of engineering trade. In one part of their works—boiler shell department—which is a bay 200 feet long and 45 feet span, having two lines of shafting down it, one on each side, 3¼ inches diameter, he could assure Mr. Mountain they had tried their best to reduce their loss to a minimum in friction. In addition to the 400 feet of shafting running in this shop they had in their tool shop, which was driven by the same pair of engines, about 250 feet of shafting, or a total of 650 feet. The power used with the tools working under normal conditions was 70 indicated horse-power, but the shafting alone driving the straps on the loose pulleys on the various machines required 38 indicated horse-power. Now, taking into consideration that the tools are not actually cutting 40 per cent. of the time there was this constant friction of 38 indicated horse-power. In an agricultural engineer's shop, employing about 2,000 men, who were always on piece-work making agricultural engines, etc., and many of the tools were light tools, the actual cutting time did not exceed 45 per cent. He had no doubt that if these machines were driven electrically the friction would be reduced considerably and very little more power used than was at present used in driving the shafting. The members of that Institution would guarantee to make engines to work at 1½ lbs. of coal per indicated horse-power, but what about their auxiliary engines? Would anyone guarantee that these engines worked with 40

lbs. of steam per indicated horse-power? He was not of Mr. Mountain's opinion that the application of electricity on board ships could not be applied with very great advantage to the shipowners, and the wear and tear considerably reduced, because the leads from the generating dynamo and the various motors about the ships would be kept more easily in repair and there would not be the constant trouble with leaky joints, etc. In reference to some of their neighbours going to the Continent to get foreign tools, he did not consider engineers had any country. The business was such that they had to go all over the world, and every improvement that was made made that world less and they became more and more dependent upon each other. He and his son had been abroad to see what had been done, and they had inspected some very large installations of electric driving. It was positive, economical, and clean. They altered their shop in 1888, and in one bay they put a rope travelling crane by Wren & Co., of Manchester, and like a great many more people they found this labour-saving tool was an extremely expensive tool, because the men, instead of exerting themselves as they had hitherto done before the crane was put up, always waited for the crane to do the work. They therefore decided to put up two additional cranes. Being under the impression that it took a great deal of power to drive the rope they were anxious to work the two additional cranes from the same rope; but on applying to the various crane makers they would not recommend this to be done, nor did they know of any place where three cranes were driven with one rope. The crane makers recommended an additional rope to be put down, but Messrs. Joseph Adamson & Co. being short of power did not see their way to drive an additional rope, and further, the crane makers could not tell them how much it would cost in power to drive the rope. They decided then to adopt electrical cranes, but the people who thought they knew said it was an act of folly. When he was over in the United States in 1890 he saw an electrical crane in Sellers, Philadelphia, which appeared to work all right. On coming home they went further into the matter, but could not find any crane makers who would recommend them to adopt, even then, electric cranes, so they decided to take the onus of making the cranes themselves. They consulted some electrical engineers, who, on account of the cost, recommended a single motor to be continually running, but Messrs. Joseph Adamson & Co. did not like this, although they designed a crane with a single motor, and when the design was finished and the details worked out the number of clutches that was necessary to get the various motions was such that it deterred them. They re-designed their cranes and went in

for "three-motor" cranes, being anxious to have the best thing that they could design, and the motto they worked on was "conscious ignorance is often safer than satisfied knowledge." They then put down a generating plant of 50 horse-power to work this crane, and this was supplied by Messrs. Siemens Brothers & Co., Limited, of London, together with the three motors for the first crane. In this matter of cranes they were guided by the fact that the output of the works depended more upon the rapidity in which the work was changed on the machines than the actual cutting speed in the machines. In taking out the powers required to drive this 10 ton crane of Messrs. Wren & Co.'s they found that a $\frac{3}{4}$ inch rope, 550 feet long, actually took as much power to drive at the required speed of 5,000 feet per minute as it did to do the whole work on the electric crane. As Mr. Mountain had wisely remarked, to reduce the high speed motor to a low speed machine power was lost. He might have added with equal truth that it took a great deal of power to get from a low speed to a high one. He submitted some figures for the satisfaction of the members of the Institution which might prove useful; they fixed a motor to drive the rope crane by which means they got the power much more accurately than by indicator diagrams, although he might add that the diagrams taken from the engine practically gave the same results. For their information the rope crane driven as before mentioned by a rope 550 feet long, running about 5,000 feet per minute, took 12·53 horse-power, of this the motor driving a belt on the loose pulley took 2·94 horse-power net. When travelling this crane at 53 feet per minute, loaded with 5 tons 10 cwt., the gross power required to travel it was 14·74 horse-power. In the cross traversing motion at 60 feet per minute the power required was 14 gross horse-power, or the actual power required to traverse the crab with $5\frac{1}{2}$ tons on it was 1·47 horse-power. The hoisting of $5\frac{1}{2}$ tons at 5·3 feet per minute was 17·1 horse-power, thus giving on the gross an efficiency of 11·5 per cent. and 43·2 per cent. for the crab alone. To lift this load at the same speed as the electric crane, namely, at 12 feet per minute, would require a total power of 22·9 horse-power. The electric crane results were as follows:—Longitudinal travelling at the rate of 120 feet per minute was 3·03 horse-power when running light, or 3·68 horse-power when loaded with $5\frac{1}{2}$ tons. The cross traversing at about 50 feet per minute was 1·77 horse-power when light, or 1·91 horse-power when loaded. When hoisting $5\frac{1}{2}$ tons at the rate of 12 feet per minute the power required was 12·97 horse-power. In all these discussions it was possible to prove anything by figures, but what he wanted them to realise was the possibility of improvements to be

effected in going through their own works, if they had not, as he had, a weakness for looking through other people's. In taking the crane as an example of the various tools in, say, bridge yards, they could see the saving was such that the reduction in the power to drive would be enormous. In the electric driven machines the power is only used when the work is being done, but with a shafting driven shop or a rope driven crane the shafting is running whether the tool is working or not. They may say the rope is knocked off when not using the crane, but the actual time employed in lifting is very small compared to the time the rope is running even then, and the same with regard to shearing and punching machines. There was a firm in Zurich who had lately extended their place and covered about three acres of land, and they drove their works by electric motors. Not only were they driving the shafting, but over the fitters' benches and over the light lathes they had put up electric driven blocks, in fact in all places where the men had to manipulate work which was more than they could handle. If the foreigner with his low wages and long hours could afford to go to this refinement how much more so should they, because, to take the case of the fitters, they all knew if he had to pull and haul at the rope or chains of a pair of rope or chain blocks fixed over his bench he would do it much more leisurely than he would if a machine did it, and, further, he would have exhausted his strength and would have to rest before he could proceed with his ordinary work. It did appear to him that electricity in its power of application was unlimited, and could be used almost anywhere and with everything and wherever intermittent power was required there was no other system so economical as electricity; and he also looked at it from another standpoint, electricity up to the present had been entirely in the hands highly educated college men. Now, he was looking forward to a v advance on this; when they got this tool in their own works the improvements would be such in the practical workings of the machine as astonish even the most sanguine. He had been told that what he w doing was very risky by a very cautious gentleman, but that gentlema now admitted, at any rate as far as electrical cranes were concerned, th it was much in advance of anything he had ever dreamt of, and his ow opinion was that the transmission of power by electricity will be as grea an advance as the locomotive was upon the stage coach. He was muc obliged for the privilege they had given him to address the members o this Institution.

Mr. D. B. Morison said to those associated with industrial establishments the President's suggestive address was particularly interesting, as

it indicated at least one method by which economies in production could be effected. These troublesome times of dull trade, together with active propagation of impossible labour programmes, had one advantage, as they gave a stimulating effect to the development of modern machinery and labour-saving appliances, so that the same work could be done with less labour, or more work for the same labour. He had an opportunity some time ago of visiting many electrically driven works on the Continent, and amongst them were those described in the President's address, and he could quite bear out his (the President's) statement as to the levelling up as handicraftsmen between themselves and their Continental brethren, especially amongst turners and machinemen, as the machines he saw in the various shops were certainly as good as could be found in this country, as was also the output of the machine per man per hour, and when they considered that these men were paid 18s. to 20s. per week, and worked ten hours a day, it made them reflect on what the commercial possibilities might be in the future if labour in this country persisted in its present reckless course. Fancy, for example, a works being driven in this country at the expenditure of 36 tons of coal a day, and a works of equal power on the Continent being driven by a possible 12 tons a day! The absurdity was most apparent when they remembered that not only was there an unnecessary expenditure of 24 tons of coal per day, but also of all the labour connected with the burning of that coal and the upkeep of the additional boilers. Many engineers looked upon electrical driving with suspicion; but he might say his experience on the Continent was such that any suspicion he had had disappeared, and when one saw factory after factory working year after year without a hitch, and at an economical expenditure of fuel unknown in the shipyards and engine works of this country, he was of opinion that those interested should begin to realise that it was commercially imperative to do something. At Newcastle one of the speakers questioned the economy of electrical driving in compact works. The basis of economy is, of course, the engine and boiler, and if works are so arranged that triple expansion or other highly efficient engines can be used, and there are no long lengths of steam pipes or indirect drives, then electrical driving would be out of the question. Seldom, however, had they such high efficiency in engine works or shipyards in this country, as generally they were the scattered non-condensing engines by the dozen, long lengths of steam pipe, low steam pressure, and utter disregard to consumption of coal. He had had an opportunity of inspecting the Belgian Royal Arsenal, which was very compact, and kept in a very high state of efficiency. Formerly the

machinery was driven by several small steam engines, but the Herst installation was such a success that the Government decided to ado motors at the arsenal, with the result that the consumption of coal about one-third of what it used to be, and there was a very mark improvement in the regularity in speed. Many of the motors were very out of the way places, and one he noticed was in a cupboard unde stair, which afforded an example of how little attention was necessa Numerous other examples could be cited, but wherever he went he s the same result, the works that were electrically driven were bei increased, and works not electrically driven were being prepared for Referring to the commercial aspect of the question, there was qu sufficient data obtainable for each one to decide for his own particul works what the cost and economy would be; but in considering Mess Dorman, Long, & Co.'s installation they had an application of electri driving which resulted in a saving of 30 tons of coal per week by t change from steam to electricity of a total of 35 electrical horse-pow Now, the dynamo for producing that power was driven by a high press engine, non-condensing, and this engine was not by any means a g one, yet it had been temporarily used for the driving of the dynamo, saved not only the 30 tons of coal a week, but the two boilers that u to produce the steam had been sold, and the men who stoked boilers had been discharged. It was, of course, rather dangerous to p down electric motors without knowing the exact character of the wor manship, as endless trouble would result from carelessly made elect installations, but if the motors were well made, well designed, hones turned out and worked within their capacity, from what he saw he w perfectly convinced they would run year after year without the slight possible trouble, and he was confident from what the President had t them that the North-East Coast engineers and shipbuilders would be long in analysing the power question at their own works, and availi themselves of the undoubted advantages of electric driving.

Mr. G. W. SIVEWRIGHT said he had not had the pleasure of hearing address read, but he was pleased to think that a paper of this descript had created such an interesting discussion. He quite admitted that driving of machinery by electric motors was a step in the right directi but at the same time he thought there was far too much stress laid u the savings in connection with electric motors, as really the grea saving was due to the use of high-pressed steam and the compound sur condensing engine. The dynamo motors are only another method

transmitting power instead of pulleys, shafting, or rope driving. He looked forward to a considerable saving in connection with this system in being able to concentrate all the engines, boilers, dynamos, etc., into one central machine station.

Mr. T. WESTGARTH—May those who have spoken and had their remarks referred to speak again?

Mr. FOTHERGILL—Not unless in explanation.

Mr. WESTGARTH said he wished to explain, in reference to what had been said by Mr. Mountain, that the engines designed were barely built when it was resolved to use electric means, and to use the power it became necessary to use the large fly-wheel for the dynamo.

Mr. GEO. WALKER (London) had had an opportunity during the summer of going to the Continent and seeing the works referred to by the President, and of examining all the motors there in use and under construction. He was very much struck with the cleanliness of the shops and the small amount of attention necessary wherever electrical motors were employed. Since then he had been to the works of Messrs. Dorman, Long, & Co., and also of the Bedson Wire Company, and found that an enormous amount of labour was being saved, in addition to a large economy in fuel. It had appeared to him since, in regard to electrical motive power, that great as the economy was in the marine engine, they might still further improve this by the use of electrical motors on board ship, especially with regard to the winches, donkey engines, reversing gears, turning gears, ash hoists, etc. It struck him also in regard to the main engine pumps that there was an enormous amount of unnecessary friction produced which, by the application of electrical power, could be considerably minimised. They had, for instance, two bilge pumps going all the day long, where one could, in twenty minutes out of every hour, do all the work required. This was simply adding friction to the machinery. He would therefore advocate that all the pumps should be driven by electrical motors. By these means, he thought, the marine engine could be exceedingly simplified and the friction considerably reduced. He did not know there were any works yet which had taken this matter seriously in hand, or devised means of bringing this result about; but he had no doubt it would not be long now before the attention of the engineering firms on the North-East Coast and the country would be turned more and

more to electrical power, as had been done, for instance, in colliery work, where the consumption of fuel per indicated horse-power in several instances had been very considerably reduced.

Mr. ROBERT THOMPSON (Past-President) said that it occurred to him during the course of the discussion that most of the speakers had treated the question as one between steam power and electricity. Where steam power was used on a single machine it might be, as Mr. Adamson stated, a steam waster. He thought the electrical engineers ought to know that there were works where considerable attention had been given to this matter with economical results. It was ten years since his firm did away with every separate steam-engine machine in their works and took to driving the machinery from one shaft; they also laid down an extensive hydraulic plant. The Institution should have all the facts before them, both in regard to direct steam driven tools and machines driven from a shaft. His firm found an immense saving by the latter method as compared with direct steam power. Having an artesian well of their own, hydraulic power proved very cheap to them. When they were all getting bitten by electricity it was well that engineers should know of the possibility of economical work otherwise than by either electricity or steam. The breakages in winter, especially with their punching machines, used to cost his firm £200 or £300 a year, but by the adoption of shaft driving this large amount was saved. These were points the Institution should know, so that in making a comparison of saving between electric driving and direct steam power they should consider driving from a shaft, where the loss was very small and the economy great, as compared with a separate engine on every machine.

Mr. G. ARNISON, Jun., said a remark had been made about electrical appliances being fitted to winches on board ship. He wished to mention that Messrs. Wilson, of Hull, were fitting electrical power to their steam winches on one of their ships as an experiment, so as to save the cost of a new winch.

The following communication was received from Mr. R. H. Tweddell on the subject:—

To the Secretary North-East Coast Institution of Engineers and Shipbuilders.

SIR,—I am prevented at the last moment from being present at the discussion on the above, and venture to ask you to lay before the meeting

the following remarks :—When in 1871* I gave my views on the economy to be effected by driving machine tools by hydraulic pressure having one prime mover, electrical transmission in its present sense was unknown—but as the same arguments apply to both systems of transmission, viz., water or electricity—I welcome such a paper as Mr. Richardson's—for when the "users" of machinery so speak—progress is much quicker than when the "seller" does so. In the letter referred to is the following passage :—"When we look round (in 1871) our large shipbuilding yards we find their areas measured by acres, and the distances over which the power given out by the engines has to be transmitted can be measured in a similar ratio. Such being the case, the transmission of power by shafting becomes both cumbrous and expensive, and this can only be partially remedied by having the engine power divided and placed at different points, involving greatly increased expenditure of capital, extra labour, fuel, rooms, stores, and insurance."

Mr. Richardson's remarks fully confirms this.

In this same letter I find I conclude :—"If the system (hydraulic) is to be adopted at all, we must take a broad view of it and start from the commencement, by laying out yards or works as if we were surveying a town for gas or water supply, and put the pipes down by the sides of the vessels, boilers, or bridges, and from them branch out the smaller arteries wherewith to feed the individual machines, which will then do the work required and no more."

With twenty-five years' experience since I first gave these views to the public I could say no more, nor do I see anything to retract. It is, doubtless, because of the somewhat limited range or number of machines which can be suitably worked by hydraulic pressure that this centralization of power—with its consequent economy—has not made greater progress; but at one shipyard, fitted out with hydraulic machines for rivetting, bending, shearing, and punching capstans, etc., 20 horse-power is only required instead of 80 horse-power had shafting been employed.

Any remarks on the economy due to hydraulic transmission (and I gave some of my reasons for believing it to be so in a paper before our Institution, read at Sunderland in 1885-6) apply with equal force to electrical transmission. As the laws affecting both systems are almost identical, the question resolves itself into a matter of suitability for certain tasks, and as hydraulic pressure is suitable for intermittent work or for rectilinear motions and not so suitable for rotary motions, it follows that a *combination* of the two systems—each with equal economical

* See letter from R. H. Tweddell to *Engineering*, Sept. 21st, 1871.

advantages and worked from one economical prime mover—is exa what is wanted; and if Mr. Richardson's address gives this matt fresh impetus, it will be a matter of congratulation to all concerne keeping trade in the country.

It does not, of course, follow that there are many cases where a c sumption of 36 tons of coal per day can be reduced to 13 by the n change from steam to electricity, and a little more information as to class of engine replaced would be interesting.—Yours faithfully,

R. H. TWEDDELL.

The PRESIDENT (the discussion having concluded) observed tha was very gratifying to him to find that his address had proved o much interest to the members of the Institution. He thought when took the chair that evening no reply would be necessary from him, speakers generally having merely amplified or corroborated his stateme but after the remarks of Mr. Mountain, who had questioned some of statements, the import of which he had not been able quite to catch should like, with their leave, to retain the privilege of saying a few w at their next meeting, and content himself now with thanking members in general for the very kind reception they had given to subject of his address, and in particular to those members who had kindly taken part in the discussion, and added so materially to value and interest of his address.

THE CONGRATULATION FROM THE HARTLEPOOLS TO THE PRESIDENT.

Mr. J. R. FOTHERGILL (Vice-President) rose, and said before t proceeded to the next paper he had a very pleasing function to perfo This being the first occasion on which Mr. Richardson had taken chair as President at a Hartlepools meeting, he begged to take opportunity of proposing that "The hearty congratulations of Hartlepools members of this Institution be accorded Mr. Richar on his election to the presidential chair of the Institution." was needless to say they were gratified and pleased to see one their townsmen so honoured. He said "honoured" advisedly, for not the Institution recognised as one of the principal Institution this country? Its papers and the discussions were frequently refe

to, and considered of the greatest value as giving the practical views of some of the best experienced men of the North-East Coast, which he need scarcely say were second to none in the country. They recognised that in Past Presidents they had had able men at the helm, and to successfully follow in their wake required no mean ability in conducting the duties of the presidential chair—duties which entailed greater responsibilities other than presiding at these meetings. Knowing how ably and successfully he had conducted the large works over which he (the President) presided, and knowing how thoroughly interested he was in all that appertains to the science and practice of marine engineering and shipbuilding, they believed that in him they had a President who would do his utmost not only to maintain but add to the reputation and success of the Institution, and he did not hesitate to predict that at the end of his term of office they would be able to congratulate him on having filled the chair with success. He therefore begged to propose that "The hearty congratulations of the Hartlepools members of this Institution be accorded to Mr. Richardson on his election to the presidential chair of the Institution."

Mr. CHRISTOPHER FURNESS, M.P., said that as a member of the Institution, and hearing of the intended meeting that night, he, being always anxious for knowledge and information, felt a desire to be with them. He, however, must apologise to them for this being his first appearance. Well, if the Institution was of only very recent origin, it would be a satisfaction to them to learn from him that its influence was possibly much greater than many of them were conscious of. He had heard of its influence and good work in various parts of the country, particularly in London, and it had always been gratifying to him to learn how influential that Institution was becoming. Now, he had ventured, as he was with them that night, to trespass a moment or two on their time to second the resolution which had been so ably proposed, congratulating Mr. Richardson upon his presidency. He was glad to learn that Mr. Richardson, who was the head of an old and long established and very excellent firm of world-wide reputation, had been elected as the first President from the Hartlepools. He (Mr. Furness) did not think they could have made a better selection, and he was glad to be present on the first occasion he had presided there. He had no doubt that when his year of office expired they would feel they had done right in electing him. He (Mr. Furness) was not an engineer, he was not a shipbuilder, he was a commercial man, and he learned that there was a great deal of

going on. He thought practical engineers and shipbuilders everything down to a minimum. They learnt that night ers and shipbuilders were a very generous people, and supplied mercial man, with an article which enabled him, as the owner icle, to do as much work with possibly $1\frac{1}{2}$ or possibly $1\frac{1}{4}$ lbs. they, the engineers, were doing with 5 lbs. It was quite clear hat either they must be making enormous profits, or else they ected with generous dispositions to give their customers all the ings and keep the worst to themselves. But then, he thought, is paying for all this waste?" His commercial mind came to his ance and said "I think it is the consumer." It was no benefit to unless they gave him a share in the profits of that economy, which d be applied in many ways. He always expected, when they were oured with the triple expansion engine, that they, practical men, would ve kept one or two in their works to reap the same benefits they, th ipowners, had reaped from them. He was not going into details, bu ne had heard that night that they could not go into any "tinpot shop in America without seeing a new motive power at work. This w electrical! He sometimes went into a barber's shop and found he co get his hair brushed by an electric machine; he had electricity lighti his house. He was told he could get his boots cleaned by the same machi and they could apply it to the making of afternoon tea in the draw room. If this were so, surely they, the practical men, should not be s to use that power which was within their reach, and he trusted soon t works on this coast would be right to the front in spite of what had bee said about other works abroad. He had no doubt that they would soo see quite a revolution in all their works, and that the power they h heard of that night would be generally adopted. He was glad to h this opportunity of seconding this resolution.

Mr. G. H. Baines said he should like, as representing one o oldest firms in that town, to add his word to the hearty congratu upon the President's chairmanship. In the Hartlepools the sincerely desirous of making progress; when they saw the head o which had done so much in clearing out and replacing th machinery (which had done such good work in its day) at of their Institution he thought they were going in the right He called attention to the fact that Mr. Richardson had to the full extent of his influence in promoting that ve object, technical education, amongst their young people.

of the most interesting features in Mr. Adamson's convincing speech was the fact that these improvements in electrical-power-use which were brought to their notice had been evolved from the brains of those who had been technically instructed. Mr. Richardson was one who in that town had endeavoured to bring this matter to the front. Before he completed his term of office he hoped they should be able to sit in a room, not vitiated as that one now was, in their new technical schools. He was sure they would be delighted that that should be so, and, further, that the fruits of their modern civilization should be brought down to the homes of all sections of the community by the right use of that technical instruction, of which their competitors abroad had been in possession so long. He had much pleasure in adding his congratulations to those put forward by Mr. Fothergill and their borough member.

Mr. FOTHERGILL put the resolution to the meeting, and it was carried by acclamation.

The PRESIDENT, replying, remarked that he was rather taken by surprise by the very unexpected vote of congratulation which had been moved by Mr. Fothergill and supported by Mr. Furness and Mr. Baines in such kind and flattering terms on behalf of the members of the Institution in the Hartlepools. He could assure them that he felt their kindness very much, and desired heartily to thank them for their good wishes. A great honour had been conferred upon him by his election as their President, an honour might he not with justice say that had been considerably increased from the fact that he had been selected to fill this important office from amongst the many able members of the Institution residing in the Hartlepools, their Council having in the first place decided that it would be desirable to have a President from the Hartlepools to give prominence as it were to the scope of the Institution, and also to show that they appreciated the valuable support the Institution received from them, and the practical interest they took in its welfare. They had heard their late President remark from the chair that he never had greater pleasure in attending any meetings of the Institution than the meetings at Hartlepool, and he should at all times, and to the best of his ability, endeavour, not only to maintain this good feeling, but in no way spare himself where the interests of the Institution were at stake, and that he would be amply repaid for any labour that was attached to the office by the valuable experience he would gain, a foretaste of which he had already received; and, further, he expressed a hope that the wide influence of the

Institution, which Mr. Furness had so flatteringly borne testimony to, would be still further extended. Mr. Furness had twitted them and also expressed surprise that whilst they were supplying their customers with such economical machinery, they should themselves be running their own so extravagantly. Mr. Adamson gave a very fair reason for this when he referred to what might be accomplished by a process of squeezing. The fact might well be, that being so obligingly busy responding to the squeezing of Mr. Furness and his friends, they had little time to devote to the modernizing of their own plant; but now this squeezing process had become so severe in the prices offered for their work, they were compelled to look round and see where the smallest saving in cost could be found. He might remind Mr. Furness and his commercial friends that they had not got the present excellent results all at once, but that during the last twenty years the advance in engineering science had enabled them to surprise them, more than once, and compelled them to modernize the machinery in their ships, and it might possibly happen in the future that they might have the pleasure of surprising them again. He, like Mr. Baines, was very glad that Mr. Adamson, who had so much helped the discussion by the interesting facts he had brought to their notice, and had laid such stress upon the importance of technical education—in the development of which he (the speaker) took a great interest. They had had their ardour rather damped lately on the other side of the water, as they were aware, but he hoped that they would, in a short time, see the error of their ways and follow the example of the (might he say) more enlightened inhabitants on this side in West Hartlepool. He thanked them heartily for their congratulations.

A BRIEF OUTLINE OF THE THEORY OF THE ROLLING OF SHIPS.

By ANDREW YOUNG.

[Read before the Institution in West Hartlepool, on November 17th, 1894.]

Note.—This paper was read before the Graduate Section of the Institution during the session 1892-3, and, at the request of some members of Council, is now re-delivered after revision and slight modification with the object of affording an opportunity for discussing matters generally connected with the rolling of ships. It does not contain any original matter but is merely a brief *résumé* of the investigations which have already been made in this branch of the science of naval architecture during the past thirty years.

The complete discussion of the transverse rolling motions of a ship as elaborated by Froude, Rankine, Bertin, and others, is of such an intricate and abstruse nature that the details can be mastered only after a somewhat extended course of mathematical study; so that on this account the work and conclusions arrived at by these writers—some of which are of considerable practical importance—are apt to be overlooked or undervalued by those who may not possess the knowledge requisite for their thorough appreciation.

The writer therefore considered that an instructive paper might be framed by collecting the principal of these results, briefly sketching out (avoiding mathematics as much as possible) the reasoning and assumptions on which they are based; and so enable some, perhaps, who may not have given much attention to the subject, to obtain a clearer knowledge of the forces which govern a ship's motion in a sea-way.

At the very outset it may be urged that owing to the peculiarity of a ship's form, the confusion of the surrounding elements—the turmoil of the sea and fury of the hurricanes which she frequently encounters, it is quite absurd to attempt any investigation which proposes to determine her behaviour under such wild and uncertain circumstances.

would, indeed, be too much to expect precision in the solution of a
em affected by so many indefinite conditions; but matters will be
plified to some extent by introducing various limitations and assump-
ns so as to render analysis applicable, at the same time erring on the
fe side by making the case for the ship as unfavourable as possible. In
his way a few approximate results will be obtained which will indicate in
a general manner the direction to be taken in seeking to diminish a ship's
rolling tendencies, and supply the means of testing the comparative
efficacy of devices arranged for attaining this desirable end.

It is easily recognised that the position of the centre of gravity of the
ship and cargo will influence to a large extent her behaviour in any
circumstances, and at first sight it is not unnatural to suppose that the
lower this point, and consequently the stiffer the ship is, the more
inflexible will be her attitude to the influence of the waves which cause
her to deviate from the vertical. Such a view would indicate a policy of
making the vessel as stiff as possible by stowing the heavy cargo at the
bottom of the hold; but experience has repeatedly demonstrated that it is
infinitely better for the ship to forego some of her stiffness which is
productive of rapid and uneasy motion. This teaching of experience is
corroborated by theory, which further enlightens us as to the best
disposition of the weights, so as to secure immunity from heavy and
dangerous rolling.

As practical instances, cases may be cited of vessels engaged in
carrying copper ore placed low down in the hold having been very
severely strained by the rapid rolling due to their excessive stiffness,
and it was only after the cargo had been raised on a platform that the
desired easiness of motion and consequent diminution of straining could
be obtained.

Again, on the introduction of armour it was popularly supposed that
the addition of such top-weight would have the effect of making the
vessels roll so much as to render them unsuitable for their purpose, but
the records of actual observations made both in England and France
proved conclusively that the behaviour of those early ironclads was on the
whole more satisfactory than that of the unarmoured vessels which they
supplanted.

Although the chief object of the whole investigation is to determine
the calculation to what danger, if any, a given ship will be exposed in
a sea-way; or, more definitely, perhaps, what will be
variation attained, and her margin of safety
isable to lead up to this final

the enquiry by the previous consideration of simpler and more ideal cases, which of themselves will yield instructive results.

Accordingly, the paper will be divided into four stages, and in the first will be discussed the oscillations of a vessel floating in a perfect non-resisting fluid which is at rest, the initial disturbing cause being supposed to have been removed. This, of course, is a very ideal case, yet worthy of consideration.

The swaying to and fro of the ship naturally suggests comparison with a pendulum, and, indeed, some of the early investigators who turned their attention to this matter carried the analogy too far, inasmuch as they assumed the metacentre to be the fixed point about which she oscillates, corresponding to the centre of suspension in the pendulum, whereas that point (M in Fig. 1, Plate VIII.) is really in motion.

There is no fixed point or axis, unless in exceptional cases, about which the vessel turns, or from which we may consider her suspended; but there is an axis about which she momentarily rotates and which is not stationary. The construction for this axis, first given by Canon Moseley,* is shown on Fig. 1, Plate VIII. F F^1 is part of the curve of flotation, *i.e.*, a section of the surface enveloping the various water-planes which cut off a constant displacement as the vessel oscillates. Assume the ship to be non-existent for a moment, and this surface solidified and rolling on the level water-plane W L without friction; then the axis about which the ship rotates will be the same as the axis of rotation of this solid whose centre of gravity is supposed to remain at G, *i.e.*, the centre of gravity of the ship, and may be found by drawing perpendiculars to the instantaneous path of any two determinable points. The point of contact F moves or slips along the plane, and thus rotates about some point in the vertical line F O; moreover, the centre of gravity G moves in a vertical line, for the forces which act on the ship are wholly vertical, having no horizontal component after the cessation of the forces producing rotation, so that the axis about which G revolves will be found in the horizontal line G O. The intersection of these two lines gives the point O which is the trace of the axis round which the ship is turning at the particular instant under consideration; hence the term "instantaneous axis."

Now, this axis obviously changes its position as the vessel rolls, and the locus cannot usually be mathematically defined; but limiting the investigation to an excursion of 10 degs. or 12 degs. on either side of the

* *Vide* Philosophical Transactions, 1850.

vertical, it will not be very erroneous to say that O does not move far from G, *i.e.*, the rotation takes place about a longitudinal axis passing through the centre of gravity. The correctness of this assumption receives some verification from the experiments of two French investigators, MM. Risbec and De Benazé, who rolled a small steamer in a dock, partly with the object of determining the axis about which she oscillated, and found it to be somewhat above, though not very far from the centre of gravity, its position varying, however, with the stowage and other circumstances.

But even this axis through the centre of gravity is not fixed in space, although fixed relatively to the ship; nevertheless, by a well-known dynamical principle, the angular motion of the vessel may be investigated by neglecting the translation of the centre of gravity, and considering only the effect of the forces causing rotation.

The mathematical expression of the principle by which all angular motion may be analysed is

$$\text{angular acceleration} = \frac{d^2\theta}{dt^2} = \frac{\text{moment of forces about axis}}{\text{moment of inertia about axis}}.$$

In the particular case of the ship oscillating in a perfect fluid, the impressed forces consist simply of the effort of the ship to right herself and is equal to W × GZ (*i.e.*, displacement or weight of vessel × righting lever), which equals W × GM sin θ or W × GMθ simply when θ is small and the moment of inertia may be written $\frac{Wk^2}{g}$, k being the radius of gyration. These substitutions being made and the equation solved, the result may be written—

$$\theta = a \cos ct + \frac{u}{c} \sin ct,$$

in which u is angular velocity when $t = o$, a = angle of deviation when $t = o$, C is a constant $= \frac{\pi}{\frac{1}{2}\text{ period}}$. This equation gives the angle of inclination at time t, enabling the motion to be graphically mapped out when the initial circumstances are given; and from it may be further deduced the time which elapses during a single roll, say from port to starboard $T = \pi \sqrt{\frac{k^2}{gm}}$, m being the metacentric height.

From this it is easily observed that if it be desired to increase the duration of a single roll, *i.e.*, the half period (the whole period being the duration of a double roll), or in other words make her angular motion slower, which is often advisable as will be brought out in the case of rolling amongst waves, two courses are open, 1st, increase the numerator of the fraction, *i.e.*, the radius of gyration; 2nd, decrease the denominator, *i.e.* the metacentric height.

Now, it is not always possible to decrease the metacentric height; in fact this may not be done beyond a certain limit, or the stability of the ship would be endangered; but at the same time there are many occasions on which it would be quite a justifiable and beneficial step to take, as in the case of the ships laden with ore previously mentioned, where GM was reduced by raising the centre of gravity of the cargo. On the other hand, the moment of inertia may be increased by moving heavy weights away from the axis of rotation, *i.e.*, the axis through the centre of gravity, a process known as "winging out" the weights, the adoption of which policy has often been attended with success, though its application should be considered in conjunction with the resistance of the water, which, will be referred to in the sequel.

In a new ship, in order to ascertain the probable period of roll (the average value of which undoubtedly has some effect on her life), it would be necessary to perform the rather laborious operation of calculating the moment of inertia from the drawings, and likewise estimate the effect of resistance, which, however, can only be obtained experimentally, so that the designer is compelled to fall back on the results of experiments with vessels similar in form to the proposed one, and make the necessary corrections entailed by an altered disposition of armour, machinery, cargo, etc. It may be here observed that as the axis passes through the centre of gravity, the moment of inertia is consequently a minimum, and has thus not been overstated in the formula for the period, the error being on the safe side.

The writer does not see that it is yet possible to fix precisely what period a ship should have for a proposed voyage, as it must be considered with reference to that of the waves she is likely to meet, so that the only guide appears to be the reputed, or better, the recorded average good behaviour of a somewhat similar ship, to whose period that of the new one may be proportioned.

In the second stage, still adhering to the assumption of a perfect fluid of unlimited depth, we introduce the complication of waves which have a definite geometrical profile and uniform period of passage. This problem has been attacked by such eminent mathematicians as Euler, D. Bernouilli, and others; but their theories, unquestionably very ingenious though sometimes yielding erroneous results, have been entirely set aside with all others in favour of that worked out by the late Mr. William Froude, which the writer will now attempt to sketch.

A brief explanation may be here necessary, for it may be considered too great a liberty to make the assumption of such regular waves with

definite profile which the ordinary appearance of a storm-lashed sea hard warrants; yet it is not wholly without justification when we know th observation demonstrates the existence of series of waves travelling onwar with nearly perfect uniformity of shape and regularity of period, and fre which most danger is to be apprehended just on account of this ve regularity. More especially is this the case with what is called a "swell a common phenomenon which may exist without apparent reason, bu which is generally the effect of a distant storm, and often proves ver efficient, though quite low, in generating heavy rolling even in large shi with great inertia.

Further, complex seas are often the result of the intersectio of two or more simple wave systems, whose effect on the ship may l studied separately and combined, as will be seen later; and as for the sma local undulations raised by the wind on the slopes of the principal wave their effect may be regarded as of comparatively little moment, and just likely to succour the vessel as add to the danger. Moreover, it is fou that when properly measured the relation between the period and t length of typical ocean waves agrees fairly well with what theory pr scribes. From these considerations it may be concluded that t assumption of theoretically defined waves is neither unjustifiable n arbitrary.

This theory has for its fundamental proposition that the particles water do not possess the swift translatory motion of the wave pro itself, but move up and down, backwards and forwards; in fact, revo in circular orbits about horizontal axes, as shown in Fig. 1, Plate I each particle being slightly in orbital advance of its predecessor, and th the wave travels onwards swiftly, although the particles composing perform only a limited excursion. This is obvious to everyone c considering the motion of a small piece of wood floating on a wave.

A deduction from the theory is that the surface of the wave is of suc a shape that a vertical section in the direction of motion would preser the form of a trochoid—the curve traced out by a point having simu taneous uniform linear and circular motion. Each sub-surface stratu which was originally horizontal becomes distorted into a simila trochoidal shape, the orbit of the particles decreasing in diameter wit the depth; diminishing, in fact, in geometrical progression, as was show by Prof. Rankine. The columns of water originally vertical are no found to be bent towards the crest, and as the waves pass on these swa to and fro, suggesting the undulations which are observed to sweep ov a cornfield under the action of the wind.

The particles of water must necessarily conform to the centrifugal action due to their rotary motion, and at the same time are subject to the all-pervading force of gravity, and also surface pressure, whence it may be readily inferred that the behaviour of any small floating body is governed by the same forces—the friction of the water being left out of account, as already premised. The resultant of the centrifugal force and force of gravity may be proved to be normal to the wave slope both by theory and a simple experiment devised by Mr. Froude. He made a little annular float of cork, on which a pendulum was suspended from an inclined mast, and observed that when placed on waves the bob preserved a central position, indicating that the pendulum is urged to take up a position normal to the wave slope, even in an extreme case when the waves curl over at the crest. And so with the ship, the general tendency is for the masts to assume a perpendicular position to the wave slope at each instant, or more correctly to the mean or effective wave slope, as it is called, for the slope of the sub-surface layers alters with the depth, but the error is on the side of safety by taking the slope at the surface.

It has been objected that this reasoning, although true as regards a surface particle, may not be applicable to a ship which penetrates some distance into the water, and destroys to some extent the wave formation in her vicinity. Let us, however, neglect this, noting that the objection has less weight the larger the wave compared with the ship.

Perhaps the chief difficulty to be overcome is the taking account of the pressures on the hull, which vary from point to point both in intensity and direction. Let the ship be supposed to be removed for a moment; then the forces which reacted upon her hull must be counterbalanced by and may be measured by those which act on the mass of fluid which fills the void caused by the removal of the ship. These forces, as we have seen, are centrifugal and gravity, and which may be considered to act at the centre of gravity of that mass of fluid, *i.e.*, the centre of buoyancy marked B in the diagram, the resultant of the two acting upward along B V, normal to the effective wave slope. Now, the centre of gravity G of the ship herself practically revolves in a circle of diameter equal to that in which B revolves (not being very far away from B); and thus at G there are two forces equal and parallel to those which act at B, but dissimilar in direction, the resultant of which G W forms with B V a righting couple, whose arm is G Z, tending to place the ship normal to the wave.

By introducing the value of this couple expressed in terms of the dimensions of ship and wave inclination and period into the numerator of

the fundamental dynamical equation and solving the result (approximations being made, however to render the equation integrable), we obtain the following expression giving the inclination of the ship at the time t:—

$$\theta = \frac{\phi}{1 - \frac{T^2}{T_1^2}} \left(\sin \frac{\pi t}{T_1} - \frac{T}{T_1} \sin \frac{\pi t}{T} \right) + a \cos \frac{\pi t}{T} + \frac{uT}{\pi} \sin \frac{\pi t}{T},$$

in which θ = angle of deviation of masts from upright ϕ = maximum slope of wave, $T = \frac{1}{2}$ period of ship, $T_1 = \frac{1}{2}$ period of wave, *i.e.*, half the time which elapses during the passage of two successive wave crests past a given point, and t denotes the time from the commencement of observation.

It will be noted that the second part of the right hand member is just what was obtained for a vessel rolling in still water, showing that the angle of inclination from the vertical at any instant may be considered as compounded of two parts, one due to the waves, the other being the angle at which she would be if oscillating in still water. Severa interesting conclusions may be derived from this equation. Let it b supposed that time is reckoned from a position at which the vessel upright and angular velocity is zero, and that $T = T_1$, *i.e.*, the period the ship = period of wave: a critical case observed by those ear writers already referred to, inasmuch as when the ship completes her r say from port to starboard, she is just in time to receive a fresh impu from the wave, and thus rolling accumulates with the procession of waves; just as in the case of an ordinary swing or a body of sold crossing a bridge, the greatest effect is produced when fresh impulses added so as to synchronise with the natural or existing oscillations of t swing or bridge. It will be found, moreover, by a proper evaluation th the increment of roll per swing due to the wave effort is equal in amou to about $1\frac{1}{2}$ times the maximum wave slope; *e.g.*, if the wave slope 9 degs., the increment of roll will be about 14 degs. Thus, after t passage of three such waves, the vessel would be on her beam ends were not for friction and the resistance of the sharp flat bow and stern. Th is roughly depicted in Fig. 2, Plate IX. By way of confirmation, M Froude generated waves in a trough of water of such a period as coincide with the natural still water period of little models of vario shapes, which on being placed in the trough were overturned or nearly after the passage of a few waves. Hence it may be reasonably conclud that it is dangerous for a ship to be rolling broadside on amongst wav whose period is the same as her own natural period in still water.

Again, if it be supposed that the period of the ship be very sm compared with that of the waves, it may be proved that the angle

which the ship's masts make with the vertical, will be the same as the angle between the vertical and wave normal, *i.e.*, the deck will be parallel to the wave slope, as in the raft-shaped body marked R on Fig. 1, Plate IX. This behaviour might have been inferred from the supposition, when we remember that the period of a ship is generally short when the metacentric height is great, as is the case in the broad shallow vessel. The motions of a ship like this will be very abrupt and rapid, or, in other words, her angular velocity will be great when amongst short steep waves, inducing a tendency to throw out the masts, and otherwise setting up severe racking stresses. Such a vessel would no doubt keep a fairly dry deck when engaged with waves of a considerable size, but her "restlessness," if it may be so termed, due to her breadth and stability, would render her rather unsuitable as a steady gun platform, provided her inertia be small.

The converse case, in which the period of the ship is very long compared with that of the wave, practically assumes her to have very little metacentric height and large moment of inertia, which may be secured by making her very narrow like the body marked S, and distributing the weight wholly at the surface or shell, at the same time keeping her stable with as little metacentric height as possible. The equation then shows that she would remain practically upright; but such a ship as this is hardly admissible in practice, besides the result is modified by resistance.

These special cases indicate what would ensue from the hypothesis that at the first wave hollow the vessel is upright and has no angular velocity; but suppose she had an angular velocity, say towards the advancing wave, betokening energy of rotation, which would just balance the wave effort and place her upright on the crest, then the formula assumes a very simple shape, and shows that at each crest and hollow she would be upright—her period of roll (not the natural period in still water) being thus forced into concordance with the wave period—and she would attain her maximum inclination at about mid-height.

The initial angular velocity required to produce such a phenomenon is

$$u = \frac{\pi^2}{2T_1} \frac{H}{L} \frac{1}{1 - \frac{T^2}{T_1^2}};$$

H being the height and L the half-length of the wave, and it may be shown that the ratio of the mast deviation from the vertical to the wave normal deviation is given by the simple expression :—

$$\frac{\psi}{\varphi} = \frac{1}{1 - \frac{T^2}{T_1^2}} \text{ in which } \begin{array}{l} \psi \text{ is mast deviation,} \\ \varphi \text{ is wave slope or wave normal deviation.} \end{array}$$

Considering now the critical relative values of T and T_1 as before, it is clear that if $T = T_1$ then ψ is infinite, as was to be expected, and if T be $> T_1$, it can be shown that the vessel always rolls towards the wave crest, and away from the crest if T be $< T_1$ and the nearer the periods approach equality the greater will be the amplitude of roll, for the denominator of the fraction becomes smaller, making ψ correspondingly large. Now the vessel is upright at the wave crest and hollow, and if the amplitude be large the angular velocity must be rapid in order to keep time with the wave of short and quick period. Under the circumstances here supposed her performance will be identically repeated on each wave—upright at crest, maximum amplitude at about mid-height, and upright again at hollow, whereas in the previous case a complete phase will be attained when T and T_1 are unequal, only after the passage of several waves.

These general conclusions are confirmed by actual experience, the ships having a long period in still water on the average roll less rapidly and to a less extent amongst waves than those with a shorter period (and consequently should enjoy somewhat longer life), for there is greater exemption from synchronism with waves of comparatively short period, which are more prevalent than long ones. Moreover, short waves are, as a rule, steeper than long ones, and as the increment of roll which each co-periodic wave can impose on the ship depends on the maximum slope or steepness of the wave, it is evident that this also tells against the ship with the short period. Hence it is generally desirable to increase the natural period of a ship in still water as much as possible by the methods previously pointed out.

Up to this point the resistance of the water has been left out of account, the general effect of which is to retard the angular velocity when rolling in still water, and cause the oscillations to gradually die out. If we could formulate the law of resistance, *i.e.*, express definitely its retarding moment at each instant in terms of angular velocity and dimensions of ship, then its value could be introduced into the numerator of the expression for the angular acceleration, which could thus be correctly calculated, as also the period and amplitude of successive rolls just as in the case of unresisted rolling; but the resistance cannot be dealt with so simply. Its value for a particular ship can be reckoned in terms of angular velocity, etc., only after certain coefficients are deduced from

an experiment with a model or similar ship, and in order to possess this data we must deduce by experiment from ships already built the value of the resistance as measured by the rate of extinction of oscillation, thus creating a storehouse of information useful in predicting the behaviour of somewhat similar ships, both in still water and in a sea-way, so that this, the third section of the paper, is devoted to the modes of examining and recording the effects of resistance.

Mr. Froude has pointed out that water offers resistance to angular motion in three distinct ways. 1st, by friction against the hull ; 2nd, by direct or keel resistance, experienced by the sharp flat ends of the vessel, bilge keels, and the like ; 3rd, waves are formed at the surface of the water, caused by the bodily motions of the ship herself, and which are found to absorb most of the energy of rotation lost by her. According to calculations made by him in connection with rolling experiments conducted on various warships, he found that the moment of resistance due to the two first causes combined could not account for more than 20 per cent. on the average of the energy which the ship lost per roll. The remainder he attributed to wave-making, which view he strengthened by general reasoning, and which is doubtless correct, when we consider that in some cases a wave only $1\frac{3}{4}$ inches high and 320 feet long would require the remaining 80 per cent. for its creation. Such a surface disturbance at an experiment would easily escape detection.

With a view, then, to obtaining the period and a measure of the resisting forces the vessel is forcibly inclined to say 10 degs. or 12 degs., and then allowed to oscillate freely. In a large heavy vessel this is accomplished by causing a body of men to run across the deck from side to side, timing their motions so that they are always running uphill, so to speak, thus augmenting the righting moment and consequently the angle of roll until it is sufficiently large.

The angle of inclination at each instant is automatically recorded on a travelling sheet of paper, on which time is also marked by a clock, the result being the somewhat harmonic figure (Fig. 1, Plate X.) in which abcissæ represent time and ordinates the angle of inclination. Each maximum value of the ordinate gives an extreme inclination, and is less than the one preceding it, the difference representing the loss of angle or range due to resistance. A curve drawn through the extremities of these ordinates is termed a curve of extinction, and is usually reconstructed as in Fig. 2, with a base line representing the number of rolls performed from the commencement of the experiment, the ordinate being the amplitude of successive extreme rolls. As a general rule, it is found that

the interval of time between successive maximum values—which is the period—is practically the same throughout, showing that ships are isochronous, even when resisted, for at least small angles of roll.

Attempts have not been wanting to establish the law connecting the resistance with the angular velocity. Some have assumed it to vary as the velocity simply, *i.e.*, $R \propto \frac{d\theta}{dt}$, but, were this so, it may be shown mathematically that the loss of range per roll (practically a measure of the tangent to the extinction curve) would be proportional to the angle or ordinate at which it is measured, *i.e.*, the curve should be logarithmic; but this does not harmonize with the facts of experience. Eminent French authorities state that it may be written $R \propto \left(\frac{d\theta}{dt}\right)^2$, but it may be demonstrated, as in the previous case, that, if this law obtained, the extinction curve should be hyperbolic; which result again does not properly represent the curves derived from actual experiments.

Mr. Froude, however, has shown both theoretically and experimentally that it may be more fairly expressed as $R = a\left(\frac{d\theta}{dt}\right) + b\left(\frac{d\theta}{dt}\right)^2$, *i.e.*, the moment of resistance at each instant varies as the first and second powers of the angular velocity; the first term representing the portion due to wave-making, the second that due to skin and keel resistance. From this may be deduced what is practically the equation to the curve of extinction, viz., that the loss of range per roll $\Delta\varphi = c\varphi + d\varphi^2$, the coefficients c and d being derived from the curve, and from which a and b may be subsequently calculated; thus the result of the experiment can be reduced to a very compendious form. A collection of these constants for several ships of different types would furnish information by which the resistance of new ships may be estimated and included in the more complex calculation for the angle in a sea-way to be described presently. If, however, this information be desired for an absolutely new type of ship a model may be constructed, weighted so as to have her radius of gyration properly proportional to that of the actual ship, and the extinction curve drawn from a tank experiment furnishing the means of obtaining the resistance constants. The curve so drawn has been found by actual experiment (just as in other cases—to be similar to the extinction curve of the completed ship, so that in this way information may be had beforehand concerning the resistance, loss of range, period, and whether the rolling is soon extinguished or not.

Now, as we see, the whole, curves a beneficial influence in modifying the blow of the wave impulses acting as a brake, thereby limiting the

angle of roll in a sea-way, so that it is desirable to increase the resistance as much as possible. For this purpose the simple plan of fitting bilge keels is often adopted, and these curves of extinction are useful in showing their effect, *e.g.*, if E in Fig. 2, Plate X., be the curve without bilge keels, F may represent it with keels of a certain breadth, and G with keels still broader, exhibiting at a glance their relative efficiency. It may be noted, however, that although their extinctive effect is very marked in still water, yet it is possible to make them too broad, and so form favourable catches for the action of the wave water by which the rolling may be augmented instead of diminished.

In heavy and comparatively slow-moving ships, with great inertia, it is clear that bilge keels will not have the same effect as in quicker moving ones, since the resistance they offer varies approximately as $(\text{velocity})^2$ so that their adoption in vessels which are reputedly quick and heavy rollers must prove beneficial.

It was brought out in the cases of unresisted rolling that to extend the period by increasing the moment of inertia is wise policy; but it was hinted that there was a limit to its adoption which will now be explained. It is clear that increase of inertia, and consequently of energy of rotation, renders the brake effort of the external resistance less efficient in modifying the amplitude of roll, so that between great inertia with corresponding less effective resistance on the one hand, and small inertia with greater liability to synchronism with short co-periodic waves on the other, there must be some condition which is the most desirable yet is most difficult to decide upon exactly. But diminution of period is to be avoided as much as possible, so that increase of resistance by bilge keels or other means as a remedial measure should always be regarded with favour, checking as it does energy of rotation excited by the action of the waves, and thus enabling the period, lengthened by "winging out" weights, to be preserved.

Mention may be here made of an attempt in one or two vessels to extinguish rolling by the use of free water which is allowed to travel from side to side in an athwartship compartment specially constructed and set aside for the purpose. The effect of the water in the chamber is precisely opposite to that produced by the men who, in running up hill, augmented the oscillations by adding to the righting moment; whereas water naturally tends to run down hill, and thus prevents rolling by partially neutralising the righting moment of the ship.

In one of two interesting papers on the value of the rolling chamber as fitted in H.M.S. "Inflexible," read before the Institution of Naval

Architects, Mr. Philip Watts remarks: "It will be probably near the truth to say that when the water chamber is about half-full the mean angle of roll will be reduced by 20 to 25 per cent. when the ship is rolling broadside on through moderate angles amongst waves of from 9·5 to 10 seconds mean period."

The discontinuance of this device seems to argue that it is practically a failure, owing, doubtless, to the uncertainty as to what quantity of water should be employed, which must be dependent on the ever-varying state of the sea; moreover, the chamber occupies considerable space in the ship, at all times valuable, especially in war vessels.

The fourth and final case, in which the vessel is supposed to be oscillating amongst ordinary sea waves of trochoidal form and regularity of period is somewhat complicated, the purpose of the enquiry being, as was pointed out at the opening, to predict the angle at which the vessel will be at each instant, and consequently the maximum angle attained, so as to find out if this exceeds the limit of safety. This limit might be stated as a fixed proportion of her angle of vanishing stability; or at all events, in the case of a sailing vessel, be determined so as to provide sufficient stability beyond the calculated maximum angle, to resist the effect of a gust of wind which may suddenly strike her in such a disadvantageous position.

This maximum inclination may be roughly approximated to in a very simple manner, for the increment of roll which the wave whose period equals that of the ship would impose on her when rolling unresistedly, viz., about $1\frac{1}{2}$ times its maximum slope, will be neutralised or balanced at the extreme inclination by the effect of resistance, and thus equal the loss of range due to that cause, which may be obtained from the curve of extinction. To take an example, if a vessel be rolling amongst co-periodic waves of, say, 4 degs. maximum slope, the increment of angle which the wave would impose in one roll would be $4 \times 1\frac{1}{2} = 6$ degs. approximately, so that if the resistance constants c and d derived from the rolling experiment be ·03 and ·004, the loss of range at φ° will be $\cdot 03\varphi + \cdot 004\varphi^2$, and $\therefore 6^\circ = \cdot 03\varphi + \cdot 004\varphi^2$ making φ, the maximum angle attained, about 25 degs. But this is an angle much beyond the limit below which the metacentric method may be legitimately employed, *i.e.*, reckoning, as has been done throughout, that the righting arm G Z equals $GM\theta$, erring on the wrong side, so that this result cannot be very accurate. There is a more correct method due to Mr. Froude, the elaboration of which formed perhaps the crowning effort to his labours in connection with this subject

By its aid the whole motion of the ship may be traced out when rolling on any waves whatever, provided their effective slope, the resistance constants, and the actual stability curve be given.

The whole difficulty lies in the solution of the equation which arises when the moment of inertia, and moment of the effective forces, *i.e.*, the righting couple as previously explained, and the moment of resistance are introduced into the fundamental dynamical expression for the angular acceleration. Mr. Froude's method consists in effecting this solution graphically, eventually drawing a curve which gives the inclination of the ship at each point on the wave slope. The process is really one of trial and error. If tangents be drawn to an assumed curve of inclinations as drawn in Fig. 2, Plate VIII., at successive points, the value of the tangent of the angle which they make with the abscissa will be a measure of the angular velocity at these points; and if these values be plotted as the ordinates to a new curve the tangents to this curve will similarly give a measure of the angular acceleration; moreover, the resistance may be calculated from the experimentally derived constants and assumed angular velocity, and the righting moment may be measured from the curve of stability; thus we are in possession of a numeric and graphic representation of all the elements occurring in the equation which must be satisfied at all points, and if on trial at each point it be so satisfied when these values are substituted, then the assumed curve of inclination is the correct one. This is essentially what Mr. Froude's method amounts to, although the details are different; the building up of all the forces into one, as shown by the ticked line on the diagram, and the checking process being carried on step by step.

This graphical method enables the effect of all the forces acting on the vessel to be taken into account provided they can be estimated, such as the effort of the wind on the sails of a sailing ship, a case worked out by Dr. White, the present Director of Naval Construction, in a comprehensive and very instructive paper communicated to the Institution of Naval Architects in 1881.

The writer believes that the results obtained by this method have been checked from actual observations of rolling at sea made by an oscillometer devised by Mr. Froude, with a view to obtaining an accurate automatic record of the vessel's inclination. This instrument essentially consists of two pendulums, one having a very long period, the other a very short period. The latter is a tube of brass filled with lead, the axis of suspension being parallel to the axis of the tube, and has a period of only $\frac{1}{10}$ of a second, being thus extremely sensitive to the ever-varying direction of

the resultant force* acting on it, which, as we have seen, is normal to the wave slope. The former is constructed as a fly-wheel having great moment of inertia, its centre of gravity being slightly eccentric to the axis of suspension which is mounted on practically frictionless bearings, and consequently, being but little influenced by the motions of the ship, remains practically motionless. The automatic records of these pendulums are made on a travelling sheet of paper, suitably controlled by clockwork, by which time is also marked, and give the inclination of the ship's masts to the upright, the inclination of the wave normal, also the period of roll, from which data the graphical method may be checked.

Another instrument, interesting on account of the principle involved, was invented by the late Prof. Piazzi Smythe for the same purpose of measuring the angle of roll. As is well known a heavy rimmed wheel rotating at a considerable velocity, tends to remain in the plane in which it was originally spun, when caused to deviate therefrom by some external force. In it a heavy wheel or gyrostat caused to revolve by a string or other means (say electric or hydraulic) round a vertical axis is centred on the circumference of a gymbal ring which has a pointer and which is pivoted on a second gymbal carried by the framework of the instrument, The framework, which is placed in a suitable position on deck, thus possesses the motions of the ship, whilst the axis about which the gyrostat revolves preserves an invariable position; and the pointer on the first gymbal indicates on a graduated arc supported by the second and placed transversely in the ship the magnitude of the oscillation. The obvious disadvantage is that the plane of rotation relatively to the horizon is unknown unless it be sighted, so that only extreme rolls from side to side can be measured by this instrument. By the addition of another pointer and arc in a fore and aft direction, the longitudinal pitching may be observed simultaneously with the transverse oscillations.

A mechanical means of modifying rolling has recently been designed by Mr. John Thorneycroft, and was described by him in a paper read in 1892 before the Institution of Naval Architects. In his apparatus a very sensitive pendulum, such as is used in Mr. Froude's instrument, is placed near the centre of gravity of the vessel, and is thus almost instantaneously affected by the varying forces acting normally to the wave slope which cause the rolling of the ship. The motions of this pendulum are aided electrically in controlling the valve which regulates a hydraulic ram. This ram moves a weight from side to side of ship so as to balance or partially neutralise the wave effort, preventing accumulation of angular

* It is this variation of force both in intensity and direction which is the chief cause of sea-sickness.

velocity and consequently increase of roll, just as free water does in a rolling chamber when acting to most advantage, *i.e.*, its motion is downhill. As fitted in a yacht of some 230 tons displacement, the ram was placed fore and aft in a horizontal position, and by means of a crank caused a tank of water to revolve beneath the cabin floor about a vertical axis. According to the testimony of those who witnessed its operation, the rolling of the vessel was sometimes diminished by about 50 per cent.

It may be noted that the same considerations and reasoning sketched out in this paper are applicable to the longitudinal oscillations or pitching motions of a vessel, the point of difference, however, in the practical application of the results being that we generally seek to lessen transverse rolling by moving weights away from the centre of gravity, but if this course were adopted in a longitudinal sense, placing the weights at the bow and stern, the vessel would have a very long longitudinal period, and would thus be very slow in rising on the waves which would easily wash over her.

The minor or secondary oscillations caused by the alternate immersion and emersion of unsymmetrical wedges of buoyancy have not been referred to, the chief object of the paper being the presentation of a brief and condensed account of the endeavours to graphically depict what Mr. Froude has called the "scenery" connected with the transverse rolling motions of a ship in a sea-way, compared with which these other motions are of little importance.

In conclusion, it must be confessed that although the period of the ship in still water has a very great influence upon her behaviour in a sea-way, yet it is seldom a determining factor in the design of an ordinary merchant vessel, save in limiting the breadth after the minimum metacentric height has been secured when laden with homogeneous cargo. Hence some may be disposed to consider the investigations in this subject as of comparatively little practical value, inasmuch as these do not enter into every-day office work, and regard with suspicion results which are based so much upon speculation and assumptions which may appear too arbitrary. Nevertheless, it has been conceded by eminent critics who have objected to the validity of these assumptions, that the results arrived at are in the main correct, and the theory the best yet advanced, both as affording an explanation of the phenomena of rolling and a means of estimating a vessel's behaviour on a given series of waves. There can be no doubt whatever, from actual experience, that it indicates correctly the remedial measures to be adopted in lessening and easing the motions of a ship in a sea-way.

DISCUSSION.

Mr. G. W. SIVEWRIGHT congratulated Mr. Young upon the very valuable paper he had written, and was pleased to note that the Reading Committee had so appreciated this Graduate's paper that they considered it of sufficient importance to read before the general meeting of members. He hoped that it would encourage Mr. Young to further investigation and that the Institution would have the benefit of his researches. Some years ago he (Mr. Sivewright) had made a very careful study of the different papers written on the rolling of vessels at sea. The majority of these papers treated the subject in a scientific way, but the most important point that seemed to be missed in some of the papers was the proportions of vessels and the stowing of cargoes. He was glad Mr. Young had devoted a portion of his paper in calling attention to these points. He believed the excessive rolling of ships was due to too much stiffness, and if the stowing of heavy cargoes low down in a ship was accompanied by extreme beam it was practically impossible to prevent rolling; indeed, he was of opinion that in the majority of cases where complaints were made it was due to these reasons. He could not agree that the fitting of bilge keels was the proper remedy to prevent rolling. There was a natural and an unnatural state in the trading or sailing of vessels, and to illustrate his meaning he would ask them to refer to the diagram (Plate XI.) which he had prepared. The midship section of cargo steamer had an easy bilge, with a good rise of floor, and when loaded full of homogeneous cargo had a reasonable amount of metacentric height. This vessel under these condition would be an easy boat, but suppose the same vessel had only her water ballast tanks filled, there would be an enormous metacentric height, and the consequence would be the same vessel under ballast conditions would be too stiff and roll excessively. The natural state of this vessel would be that probably 80 per cent. of her voyages would be made loaded and the remainder in ballast, which latter would be an unnatural condition. He contended it was not right to fit bilge keels to suit a vessel that was sailing in ballast instead of being loaded with cargo. The only result in fitting bilge keels is to set up skin friction; he thought this was a very undesirable thing to do when speed was required, as they well knew that to get speed economically it was necessary to reduce skin friction. He believed, in some experiments

made some time ago, that the fitting of bilge keels to a boat having a speed of 13 knots had reduced the speed fully half a knot. Besides in going through locks or alongside quays, loading berths, etc., bilge keels were a source of danger. For some years now he had designed and built a large number of ships in which neither keels or bilge keels were fitted, but at the same time he was careful to see they were good proportioned vessels with an easy bilge and a good rise of floor. He believed if owners would allow shipbuilders to construct vessels of easy dimensions and would stow their cargoes properly, they would have a very much more economical working vessel for all-round trading than with shallow vessels of extreme beam. He had just received information that two of the largest steamers trading out of Liverpool (which were originally fitted with bilge keels) had had their bilge keels cut off with gratifying results, but, at the same time, he might mention they were vessels of easy dimensions. In battle ships they had different conditions to contend with from ordinary cargo boats. They required in these vessels an enormous beam for gun platform, etc., and in case of being pierced by shot or any of the compartments being flooded they required a large amount of metacentric height to give them plenty of stability; if this was not done there would be a tendency with a low metacentric height (supposing one of the chambers to be flooded with water) for the ship to capsize. To prevent the rolling of this type of vessel he believed they were accustomed to fit bilge keels fully 3 feet in width. The fitting of a ballast tank on deck, as advocated by one of their members (Mr. Maxwell Hill), he considered was a very sensible plan of reducing the metacentric height of a ship when in ballast, and he thought that if this plan became universal it would considerably reduce the rolling of vessels without the aid of bilge keels.

The discussion was adjourned, and the meeting dissolved.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

ELEVENTH SESSION, 1894–95.

PROCEEDINGS.

THIRD GENERAL MEETING OF THE SESSION, HELD IN THE LECTURE HALL OF THE SUBSCRIPTION LITERARY SOCIETY, SUNDERLAND, ON WEDNESDAY EVENING, DECEMBER 19TH, 1894.

ALDERMAN THOMAS RICHARDSON, B.A., J.P., PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the Second General Meeting of the session, held in West Hartlepool, on November 17th, 1894, which were approved by the members present, and signed by the President.

The ballot for new members having been taken, the President appointed Professor R. L. Weighton, M.A., and Mr. J. R. Fothergill to examine the voting papers, and the following gentlemen were declared elected :—

MEMBERS.

McBride, William, Engineer and Assistant Manager, Warren Cement Works Cottages, Hartlepool.

Taylor, John, Supt. Engineer, 53, Heaton Park Road, Heaton, Newcastle-upon-Tyne.

Toovey, Alfred F., Inspecting Engineer, Ovington Cottage, Prudhoe, Northumberland.

Yale, Thomas P. O., Engineer, 8, Belgrave Terrace, Newcastle-upon-Tyne.

ASSOCIATES.

Harrison, Thomas, Engineers' Merchant, 9, Bridge Street, Sunderland.

Meek, John George, Accountant, 10, Belle Vue Road, Tunstall Road, Sunderland.

GRADUATES.

Ashton, Arthur W., Engineering Student, 29, Falconar Street, Shieldfield, Newcastle-upon-Tyne

Bennet, Arnold, Naval Architect Student, 47, Grove Street, Elswick Road, Newcastle-upon-Tyne.

Borthwick, Robert J., Engineer, 8, Kensington Terrace, Newcastle-upon-Tyne.

Hancock, Bede, Engineer, St. Bede's Vicarage, Sunderland, M.

Jonas, Owen M., Electrical Engineer, 23, Lovaine Crescent, Newcastle-upon-Tyne.

Laing, Hugh, Shipbuilder, Thornhill, Sunderland.

Mellanby, Alexander L., Engineering Student, 3, Leazes Terrace, Newcastle-upon-Tyne.

Palmer, Henry G., Electrical Engineer, 16, Bolton Terrace, Newcastle-upon-Tyne.

Robson, Nathaniel E., Engineer, 32, North Terrace, Wallsend-upon-Tyne.

Robson, Robert, Electrical Engineer, 166, Rye Hill, Newcastle-upon-Tyne.

THE INAUGURAL ADDRESS.—REPLY BY THE PRESIDENT.

The PRESIDENT said he felt highly gratified that his address had been the means of eliciting so much valuable information from the various members who had taken part in the discussion, and he had great pleasure, on behalf of their Institution, in thanking Mr. Panton, Mr. Bedson, Mr. Adamson, and other visitors who had so kindly contributed the results of their practical experience in electrical driving, and so materially added to the value of the proceedings. It was somewhat a departure in their procedure for a reply to be made on a presidential address, but in view of Mr. Mountain's remarks he felt some explanation was necessary, although he was in perfect accord with Mr. Adamson's opinion that "an engineer had no country," but was a member of a universal brotherhood, whose object was progress. He might mention, however, that in the preparation of his address he placed himself in communication with Messrs. Siemens & Co., the Wolverhampton Electric Co., and the Companie International d'Electricitié of Liége, so as to obtain, if possible, the results of the best general practice. Messrs. Siemens favoured him with some valuable particulars, but requested that no publication should be made in view of the paper Mr. Siemens had just read before the mining engineers; and the other firm, although sending some interesting particulars of installations, had no comparative results which were necessary for his purpose. The object of his address was, however, not to advertise, or compare the merits of various firms of electricians, but rather to submit to the members of this Institution reliable data concerning the best examples of electrical driving in other than the workshops of electrical engineers. With regard to Mr. Mountain's remarks on independent motors, it was a very simple matter to determine in any particular case what would be the limit for the greatest commercial success. In the Liége factory, for example, it would have been highly absurd to drive with independent motors thousands of small machines, which were mostly automatic and continuous in their action, and it would be equally unwise to adopt one large motor in an engine works to drive travelling cranes, large lathes, and other massive tools, which worked very intermittently; but it was unnecessary for him to amplify Mr. Adamson's remarks in this direction, as the valuable

illustrations he had given clearly showed the careful attention this branch of the subject warranted. The broad field of economical electrical driving was clearly defined, as it was evidently not applicable to cases where an engine could be applied direct to a machine, and his only excuse for mentioning such an absurdity was that reference had been made to that fact during the discussion. It was also, for example, very doubtful whether existing cotton mills could be converted, as the only possible economy was that obtainable from the reduction in frictional loss by adopting independent motors, and commercial success could only follow when the saving in power exceeded the loss due to electrical transformation by an amount sufficient to justify the capital outlay. They, however, were not associated with refinements such as these, but had to deal with extravagant losses due to high pressure engines scattered over a large area, and for such cases electrical driving would be an undoubted success. There were exceptions, of course, even in this district, and Mr. Thompson had given them an interesting example where shipyard machinery was all belt driven from a single engine, which afforded an illustration of a case where electrical driving was not applicable. The question of applicability was easily determined, and the valuable information elicited during the discussion would be of great assistance to those who gave the subject their attention. In concluding his remarks, he could only repeat that it had given him great pleasure to have been able to introduce a subject which had proved of such general interest, and he trusted that the electrical engineers of this Institution would favour them ere long with further contributions.

ADJOURNED DISCUSSION ON MR. ANDREW YOUNG'S PAPER ON "A BRIEF OUTLINE OF THE THEORY OF THE ROLLING OF SHIPS."

Mr. E. W. De Rusett said he had very much pleasure in bearing his testimony to the value of this paper, which showed a great deal of earnest, patient reading, and he thought would be very useful to appear in their *Transactions*. Mr. Sivewright, at their last meeting, deprecated the use of bilge keels in, he thought, rather a summary manner. The fact is, these appendages had been used very much, not only on new ships, but also on vessels which had been previously worked without them. He had a case of the latter description in mind, that of the "Ormuz," one of the Orient Company's boats, which used to roll heavily. The company went to the expense of over £1,000 to have bilge keels fitted to that vessel. They were about 180 feet long and 2 feet 3 inches deep. The result was a considerable improvement in the ship's behaviour at sea so far as the rolling was concerned, and, being a passenger ship, it was of immense advantage to obtain a steady platform. He (Mr. De Rusett) enquired into this case, and was fully assured that the bilge keels did not in any way affect the vessel's speed. The revolutions were almost identical in each case, and he understood the company have since gone on fitting them to their other liners. He thought there was reason in this procedure. He had noticed that the wooden North East Coast sea tugs were clincher-built boats, and the cobles were similarly constructed. He had asked, "Why do you prefer your boats clincher-built?" The reply was "because they are much more weatherly, they roll less, and stand up better against a sea." In point of fact, the overlapped planking of these clincher boats practically formed bilge keels all along their sides, and offered resistance to the rolling of these handy craft. Since he had been in the North his firm had built two large fast passenger liners, which were fitted with unusually large bilge keels, they being about 1 foot 6 inches deep and 120 feet long, the vessel's length being 345 feet between perpendiculars. He took a voyage for a fortnight in one of these vessels. She had also fins fitted well below the water forward to prevent pitching, and one could hear the whish the swell made against the fins as the waves rose and fell past the vessel's bow, she remaining practically unmoved. As a matter of history these bow

fins were afterwards taken off, as they were considered to interfere somewhat with the speed of the vessel, but the bilge keels were retained. Some tank experiments were made by Mr. Caws with the models of these steamers with and without the bilge keels, and he (Mr. Caws) could tell them that the resistance in smooth water was not perceptibly increased even with such large keels. He had frequently asked captains and others, "Do you find any difference in the speed of your ship when she begins to roll?" "Yes," they said, "a very perceptible difference, as the speed falls off at once." Although a smooth water experiment showed very little if any increase of resistance, the members could readily gather that if they could keep their vessels steady at sea the propelling power would be more efficaciously employed, and steam would be kept more easily, as stokers worked better off a steady platform. As the author had pointed out (page 67) the result of Mr. Froude's observations, viz., that the resistance to rolling by the skin of the ship, and the direct resistance of bilge keels was something like 20 per cent. of the whole, the remaining 80 per cent. was due to wave-making. That bilge keels are a great wave-making agency as they rock backwards and forwards is clear, hence their value in steadying a ship among waves. A very important point was mentioned by the author in pages 59-60, and that was the desirability of securing a suitable metacentric height. Now, they could not ensure this, excepting, possibly, in thoroughly organised liners, such as those carrying passengers and having water ballast, over which the commander had full control, regardless of his load-line. He (the speaker) had taken a trip in one of the passenger vessels of a large company in order to watch this point, when he learned that the G.M. height necessary for comfort was secured by adjusting the water in the ballast tanks, the captain stating that he generally aimed at getting about 15 inches of metacentric height. But in the ordinary cargo boat this could not be secured, as she was loaded to the Plimsoll and started away without much regard to G.M., and the captain would not care to risk the loss of surplus buoyancy by filling ballast tanks. Therefore, it appeared to him (Mr. De Rusett), it was far more satisfactory and reliable to resort to bilge keels to steady ships than to place any reliance in stevedoring for this purpose, as they were a mechanical expedient always available and operative. He thought this stood to reason. Further, his firm had tried a number of experiments with the model of the "Warrimoo," and found the bilge keels considerably more effective than the ordinary single line keel. They tested this in the Tyne, as it was found even in a relatively large tank the backwash affected her roll period considerably, the waves neutralising the experi-

ment. The effect obtained by the model was exactly borne out by the ship. He thought he was justified in giving them this information, because as other members were so ready to come forward and give "wrinkles" out of their experience, and he was pleased to give his.

Mr. MAXWELL HILL said he had not had the opportunity of hearing Mr. Young's paper read at their last General Meeting in Hartlepool, but having had a copy of the paper he had had an opportunity of looking through it. He congratulated Mr. Young on the very able manner in which he handled his subject. He noted that the paper was read before the Graduate section during the session 1892-3, and he could only say that, if it was a fair sample of the papers read before the Graduate section, there was not much to fear for the continued success of the Institution. As Mr. Young pointed out, the discussion of the transverse rolling motions of a ship, as elaborated by many writers, was of such an intricate character that it required a high mathematical training to be able to follow the same. The manner, however, in which the writer of this paper put the matter before them, showed that he had the question before him well in hand. He did not propose to follow the paper from a scientific point of view, but rather to make one or two remarks more of a practical nature. With reference to the stowage of cargoes, the writer of the paper very aptly mentioned that, at first sight, it was not unnatural to suppose that the lower the centre of gravity of the ship and cargo, and consequently the stiffer the ship is the more inflexible she would be to the influence of the waves; although experience had taught them in dealing with heavy cargoes, such as copper ore, that to get over the excessive stiffness it was necessary to fit platforms, or trunks, in order to raise the centre of weight. He was, however, of opinion that too many shipowners and captains acted upon the first impression, that of keeping the weight well down, and in many cases making the ships far too stiff, and consequently uneasy rolling. With reference to the fitting of bilge keels he would not go quite so far as Mr. Sivewright as to do away with them altogether, as there were many forms of hull where they were beneficial. He did, however, think that they were fitted in many well-proportioned vessels, where they were of little value in counteracting rolling. He contended that in many cases the fitting of bilge keels did not receive the amount of consideration due to them; he meant as to the best position, the line of same, and the extent to which they were carried fore and aft. He was of opinion that they were, in many cases, carried too far fore and aft, and the ends became of such a form as to materially affect

the speed of the vessel. He rather advocated fitting them much shorter, and making them slightly deeper, where the form of section would admit of same, without running any undue risk of fouling quay walls, dock sills, etc. In the paper on "Qualities and Performances of Recent First-class Battleships," read by Sir W. H. White before the Institution of Naval Architects, at the spring meetings that year, the question of bilge keels received a considerable amount of attention; this was chiefly due to H.M.S. "Resolution" having encountered very bad weather, having rolled considerably, and having had to put back. It was rather suggested by some of the critics that a mistake had been made in not fitting bilge keels to her. Sir W. H. White proved clearly that the question of fitting bilge keels had received careful consideration, and it was decided not to fit them, and as he (Mr. Hill) had the construction of the "Resolution" in hand until after she was launched, he knew that they were not originally intended to be fitted. Bilge keels had since, however, been fitted to this class of ship, with the result, he believed, of considerably reducing the rolling, and with very little effect on the speed. One of his reasons for speaking on this paper of Mr. Young's was because he found that at the discussion that took place on it at Hartlepool last month, Mr. Sivewright referred to him in connection with a new arrangement of deck water ballast tanks that he had recently had fitted in a vessel built at Hartlepool and from what he (Mr. Sivewright) said he took it that he had seen this vessel, and was pleased to note that he spoke favourably of the plan adopted. As one of the objects of Mr. Young's paper was to afford an opportunity for discussing the rolling of ships, and as one of the reasons for fitting these deck tanks was to raise the common centre of gravity of the vessel when in ballast, and consequently ease the rolling, it would perhaps not be *out* of place if he made a few remarks with reference to the fitting of these tanks. It somewhat recently came to his knowledge that it was no uncommon practice for vessels going out in ballast to take a quantity of loose stone, or rubble ballast on the after-deck, for the purpose of easing the rolling, and also to better immerse the propeller, hence the idea of fitting deck tanks. The modern cargo vessels were more or less deficient in water ballast to properly immerse the propeller when in ballast trim, and if they put any more in the bottom they not only shut out cargo space, but they increased the stiffness of an already too stiff ship. Unfortunately in these depressed times, with unprofitable freights, it was a common practice to send vessels out light to get a homeward freight, the consequence being that a large percentage of the voyages were made in a light condition, and it was therefore necessary to consider the behaviour

of vessels in a light as well as in a loaded condition. The vessel in which these deck tanks were fitted was of the following dimensions (see Plate XIA):—304 + 42·6 + 20·9 4,000 tons dead weight on 19·6, and was of the partial awning-deck type, *i.e.*, with the well aft, the arrangement of fitting them was as follows :—The sides of the tanks were formed by two girders fitted on the top of the after-deck, standing about 3 feet 3 inches high, and placed 12 feet each side of the centre line of the ship and extending from the poop to the break, and so arranged that they passed through the engine room bulkhead and overlapped on to the engine casing coaming plates, thus forming continuous girders in connection with the engine and boiler casing right aft to the poop. The space between these girders was plated over from side to side and formed the top of the tanks, the quarter-deck forming the bottom. In this class of vessel it had been found that some showed signs of weakness at the break of the deck, *i.e.*, just abaft the engine room bulkhead, and Lloyd's had insisted upon the main deck being carried into the hold abaft the engine room bulkhead, to form a scarp or overlap with the quarter-deck, which meant a breakage of stowage. By this arrangement of deck tanks in the ship referred to, the extending of the main deck abaft the engine room bulkhead was avoided, the partial awning deck being extended about 12 feet abaft the engine room bulkhead, and thus forming a scarf or overlap with the quarter-deck, the space being utilized partly for fresh water and partly as a ballast tank. The capacity of the deck tanks as fitted was about 175 tons of water, and this with the weight of material in their construction had the effect of raising the common centre of gravity about 1 foot 3 inches; this was with the ordinary tanks full, also bunkers full, and even then there was still 7 feet 3 inches metacentric distance left. The raising of the centre of gravity 1 foot 3 inches would have a material effect in reducing the severe straining and rapid rolling due to excessive stiffness. The arrangement of these tanks added considerably to the structural strength of the vessel, so much so that Lloyd's made an allowance in the freeside of the vessel referred to on account of same. The filling of these tanks had the effect of immersing the propeller an additional 18 inches, which minimised vibration and improved the speed. The top of the tanks formed a means of communication in bad weather from the poop to the bridge, without going into the well, hand rails being fitted along each side. The means of filling was by a pipe connected to the donkey pump, and they were drained through cocks on to the upper deck, the water passing overboard through the ordinary scuppers. The ship in which these tanks were fitted was now on her

first voyage, having gone out to the East in ballast, and with the deck tanks full, and they now expected a report daily, as to the effect of the tanks, which they hoped would be such as to justify their having fitted them.

Mr. W. Hök, in offering a few remarks on this paper, said he would first touch upon the theoretical aspect of the matter, and then upon the practical side. What he had to say would not be very encouraging, for he could not help holding the view that the theory in its present state was very imperfect. First, with regard to the position of the axis about which the ship was momentarily rotating. With due respect to that eminent theorist, Canon Moseley, he could not possibly see how his construction of it could be correct. It might possibly be true in special ideal cases, but in nature those cases had no existence. The reason was that he had entirely neglected the influence of the forces of water resistance, and also the variation of displacement throughout the roll. He had treated the problem from a statical and only partly dynamical point of view. If his construction were true the whole of the ship would, in many cases, have a considerable lateral translation during the roll, and he did not think anyone who had been on board a rolling ship had noticed much lateral translation taking place. He would not attempt to give a solution of the problem, for it could only be solved by making a large number of experiments. Nor did he believe that the ship's masts tended to take up a direction normal to the effective wave slope. It might be true of an infinitely small body, but could not be true of a ship which was large in proportion to the wave. Neither did he think that the rolling was isochronous. Now, the theory was based on the principal conceptions that the axis of rotation passed through the centre of gravity, that the ship's masts tended to place themselves normal to the wave surface, and that the rolling was isochronous. Hence it followed that if his arguments and surmises were true the present theory needed considerable amendment before it could for any length of time stand the test of experience. In order to show them that there was some ground for these strictures, he would quote from a paper written lately for the Institution of Naval Architects by M. Bertin, the eminent Frenchman, who had been a great authority for the last thirty years on the subject. He commenced—"I do not think that I do any wrong to the various authors who have treated the question of rolling on a non-synchronous wave when I say that the calculations hitherto attempted have not

greatly advanced the question. Naturally, I make no exception in favour of what I have hitherto accomplished myself," etc. This was a significant utterance of a man who had devoted himself assiduously to the subject of rolling for the last thirty years. His paper was worthy of careful study by those who were interested in this matter. Now, the only way of obtaining a true conception of the rolling of ships was by making numerous experiments on ships and models. This could be easily done if shipowners, captains, and builders co-operated in the matter, and if Mr. Young's paper had awakened an interest in this difficult subject he was sure he would be well repaid for the trouble in putting it before them. Coming to the practical aspect of the matter, what they wanted was a slow rolling ship with a minimum angle of roll; and what they had above everything else to guard against was a large angle of roll. What now principally determined the rolling were the forces of inertia, the righting force, and the forces of water resistance. Speaking generally, those forces were inter-dependent, and this fact constituted the whole difficulty in treating problems of rolling. He did not think it was safe to lay down any hard and fast rule with regard to the influence of the forces of inertia and the righting force in reducing the maximum angle of roll to a minimum, but what was safe to say was that increasing the forces of water resistance would always reduce the maximum roll. This was why loaded ships generally rolled very much less than light ships. In practice the reduction of the maximum roll was effected by increasing the immersion, and by fitting bilge keels. The bilge keels need not be long, but should be of considerable depth to be of any use. There was a case which under certain conditions was dangerous, and to which he therefore would like to draw their attention, *i.e.*, a ship with relatively large forces of inertia, small righting forces of stability, and small forces of water resistance. Such a ship might be a battleship, with heavy top armour and guns, with round midship section, and small stability. In such a case the roll would be slow, which would reduce the effect of bilge keels. So, in this case, the problem of reducing the maximum roll was not easy to solve. The other case was a merchant vessel, light, with her coal in the upper bunkers and bridge, and the ballast carried on the upper deck in order to reduce the statical stability. He did not think practical seamen would countenance this kind of arrangement, but it had been seriously suggested as a means of reducing the rolling of the modern broad and shallow cargo steamer when light.

Mr. ROBT. THOMPSON (Past-President) said he simply wanted to add his testimony to what Mr. De Rusett had said with regard to bilge keels affecting the rolling of ships. In 1883 his firm built a vessel 383 feet long and 46 feet beam, with a flat keel, and without bilge keels, which was the owner's particular wish. The vessel was run for some years in that condition in the American trade. Three or four years ago bilge keels were fitted to the ship, and since then there had been a very marked improvement in the ship's rolling, as compared with the rolling previous to the bilge keels being fitted. The fitting of the bilge keels had not affected the speed of the ship. These last few years his firm had given very close attention to the matter. They had built a steamer of about 2,800 tons deadweight, being a sister ship to one built three or four years ago, with a bar keel. The vessel built this year had a flat keel and bilge keels. They had had a letter from the captain to say that although his previous ship was a good one—it had been part of the contract that the lines were not to be interfered with—the captain reported that the new ship rolled more easily than the previous one. Experiments, as spoken to by Mr. De Rusett, had been borne out by experience; of course, bilge keels would affect the speed of the ship if they were not put on properly and that was where the test lay. If they put them lower at the after-end than the fore-end they became a wedge, and she had to drive through it—but put them up on the water-line according to the trim in which they were going to run the ship, and also see that they were not abnormal to the size of the ship. If they put large and long bilge keels on to a small ship they would have the speed affected to some extent, the same as if they had the bilge keels lower at the after-end than the fore-end. He said that to show where the bilge keels would affect the speed and make the vessel slower; but his opinion was, after very close calculation and experiment, and also by the test of actual experience, especially in fine passenger boats, that where they had been fitted with a bar keel, and other ships had been fitted with bilge keels, they found that the bilge keel ship, year in and year out, with the average of weather they thus got, was the faster vessel in the twelve months, simply because she rolled easier, the propellers were kept driving steadier, and the vessel got better through the seas. His firm had in two cases distinct proof of this, and he was sure he was speaking quite within the mark when he said these boats gave better speed results where the bilge keels were fitted as compared with the vessels fitted with the bar keel.

Mr. J. R. FOTHERGILL (Vice-President) remarked that he rose for the purpose of asking a question. It was generally contended, if bilge keels

were to be efficient, more particularly when fitted to cargo steamers, they would require to be of such depth as to become an element of danger. Would Mr. De Rusett express his opinion as to what he considered should be the depth of an efficient bilge keel, say, for a steamer of 330 feet long by 40 feet beam? He (Mr. Fothergill) understood Mr. Sivewright's contention was, not that bilge keels would not reduce rolling, but to be of real benefit they would require to be of such depth as would most probably, in the case of cargo steamers, be productive of considerably more harm than good, and he must say that he was of the same opinion. There was no doubt by careful and proper loading in the distribution of the weights much could be done to reduce rolling, but, particularly in these days of poor freights, they neither had the time or opportunity to do so. They frequently had to load at two ports, first with light cargo and then fill up with heavy goods. They could either take or leave it, but in these days they were glad to get what they could. Mr. Thompson had spoken as to the position in which bilge keels should be fixed, and pointed out if not fixed in a certain position they would be detrimental to the speed of the vessel. He should like to ask Mr. Thompson how this could be done under conditions of different trim, for instance, such as the difference of trim between light and loaded ship?

Mr. E. W. De Rusett replied that with regard to the size of the bilge keels, of course it depended very much upon what kind of bilge the vessel had. In determining the size of the bilge keel they had to consider the batter of the ordinary quayside wall, so that the bilge keel would be protected from coming into contact with it. A bilge keel 12 inches in depth for about half length of the vessel was as much as could be got on the sharp bilge of a cargo boat; but from his experience a short, deep bilge keel was the better, as in the case of the "Warimoo," and her sister vessel the "Miowera." There was a common error that bilge keels would get knocked off the first time the vessel was docked. One of the vessels he mentioned—the "Miowera"—got on the rocks, and remained there some time. He afterwards saw the vessel in dry dock and examined her bottom carefully, when it was observed the starboard bilge keel was rather hurt, but the port keel was untouched, although the bottom was terribly battered. The second time she got on the rocks the starboard bilge keel was scarcely touched, and the port keel not touched at all. If well placed, and of suitable size, bilge keels would stand any ordinary wear and tear, improve the steaming of the vessel, and materially aid in producing a comfortable ship, regard being also had to storage and form, as was so emphatically pointed out by Mr. Sivewright.

Mr. F. Caws said he had been several times requested to make experiments in his tank upon bilge keels, and these experiments bore out very remarkably some of the observations made that night, particularly as to length. His experiments proved that if bilge keels were made so long as to interfere with the lines of the ship at the ends, that did affect appreciably the resistance; but in the case of vessels having long parallel middle bodies, the bilge keels could be extended, of course, much more than in finer ships. His experiments proved that bilge keels, so long as they partook more of the nature of bilge "clogs" than long keels, had really no appreciable effect on the speed. The "fins" spoken to by Mr. De Rusett were found in the experiments to have a very marked effect upon the speed. Indeed, when the experiments were worked out he went so far, on the occasion Mr. De Rusett alluded to, as to say he believed the fins would have an effect in reducing the speed of the ship in question by about three-fifths of a knot, and that was afterwards proved to be true, because when the twin ship was tried on the measured mile without fins she went three-fifths of a knot faster than the original ship previously tried under similar conditions with fins.

The President declared the discussion closed, and Mr. Young's reply was deferred till the next meeting.

AN ACCOUNT OF SOME EXPERIMENTAL STUDIES OF SHIP ACCELERATION AND FLUID RESISTANCE.

By FRANK CAWS.

[Read before the Institution, in Sunderland, on December 19th, 1894.]

In the paper which the writer had the honour to submit last year to this Institution, space would not allow him to refer to a prolonged series of experiments which he made previous to his invention of the pendulum speed-power meter, and which ultimately led up to that invention.

The two-fold object of these experiments was:—1 (Practical). To obtain an apparatus and method by which, within a room of moderate size, and at small cost, the shipbuilder and naval architect could find the speed-powers of any ship from her small model. 2 (Scientific). To learn the principles of fluid resistance. The present paper will relate exclusively to object 2; and will deal with one side only of a many-sided enquiry.

The tank (see Plate XII.) in which these experiments were made was 40 feet long, 4 feet wide, and 4 feet deep. By the kind permission and help of Messrs. C. S. Swan & Hunter, it was specially constructed in 1884, in an old warehouse in their East yard at Wallsend. It remained there during a number of years, till the old warehouse was pulled down to make room for the new joiners' shop which now overlaps the site.

At one end of this tank two vertical iron poles were erected, graduated from top to bottom in terms of feet. Fixed across the top of these two poles was a short broad board, facing the lengthway of the tank. Upon brass brackets, secured to this board, two distinct sets of "frictionless" wheels were mounted, one set of wheels to each pole.

Each set of wheels consisted of one centre pulley, revolving frictionlessly on the rims of four supporting wheels, in the usual manner of an Atwood's machine. At the opposite end of the tank, at a level not very high above the water, was another pulley, mounted on fine centres.

The towline passed from the bow of the ship model floating in the tank, round under the last named pulley, and thence back, over the full length of the tank, to one of the two first-named pulleys, and then down to the towing weight suspended therefrom.

The other one of the two first-named pulleys supported two unequal weights hung in counterpoise, employed on Atwood's principle for measuring time. On the sketch (Plate XII.) the heavier, *i.e.*, the descending or "down-time weight," is shown at the top, ready to come down; and the lighter, *i.e.*, the ascending or "uptime weight," is shown at the bottom ready to go up. The towing weight also is shown at the top ready to descend, and the model is shown at one end of the tank ready to start for the other end. Please observe, the underside of the towing weight in this starting position is exactly level with the underside of the down-time weight, and these two weights thus toeing, so to speak, the scratch level, are ready to race each other down in front of their respective poles, until they are arrested by their respective brackets. Near the bottom of the poles you will observe these projecting brackets, one to each pole. These brackets are of cast iron. They are made to slide up and down their respective poles, and to clamp by a side screw at any desired level; and each bracket is fitted with a vernier scale in terms of feet, by the aid of which the adjustment of any level can be made with the utmost accuracy.

As shown in Plate XII., the towline is in tension from the towing weight; and yet the model remains still at that end of the tank nearest to the poles. Likewise the lighter time weight remains motionless at the bottom, and the heavier time weight at the top. Neither the ship nor the time weights can move until the cotton thread leash which connects the stern of the model to the underside of the lighter time weight is burnt or otherwise severed. This leash line after leaving the lighter time weight passes plumb down, and under a little staple, or eye, fixed to the tank end; and from that staple, or eye, it passes horizontally forward till it reaches and is fastened round a little windlass mounted on the poop of the model. By means of this little windlass the operator is able before the start to adjust the towing weight and down-time weight to the scratch, or starting level.

All being thus truly adjusted, the burning of the leash liberates instantly the two systems which had been restrained by the one leash common to both; and, as this leash was the only connection between the two systems, the act of burning it renders them absolutely separate and distinct from each other; so that the towing weight and its model forming one system, and the uptime weight and down-time weight forming the other system, each system proceeds to move quite independently of the other.

Now it will be seen that the travel of the model in a given time is represented and measured by the descent of the towing weight in that time.

The time in question is marked by the descent of the down-time weight. Knowing beforehand that the travel of the down-time weight in, say, 1 second or 2 seconds, or in any other predetermined time, depends upon how much heavier the down-time weight is than the uptime weight. If the uptime weight weigh nothing, then the down-time weight will in 1 second fall 16·1 feet. If the uptime weight weigh the same as the down-time weight, the latter will not fall at all. Between those limits the operator can adjust the weights so as to make the descent of the down-time weight in any given time whatever he pleases. And he can thus employ the time weight system to mark, in very small fractions of time on a very large and accurate scale, the time in which the model is travelling horizontally the same distance as the towing weight simultaneously travels vertically.

But in order to employ the time weights for this purpose it is necessary not only that the down-time weight and towing weight start from scratch simultaneously, but also that they stop on their respective brackets at the same moment as one another.

Simultaneous starting was effected by burning the leash, common to both systems, as above described. Simultaneous stopping was effected by the use of electricity, in a manner which shall now be explained.

Each of the two brackets, which arrested the two falling weights, had a little hole through the middle of its flat table. Before the burning of the leash there was planted in each hole a small round stick or plug of lignum vitæ (a non-conducting material) the top end of each plug being allowed to stand a little above the level of the bracket table. Round each plug there was a ring or zone of platinum (a conducting material) let in almost flush, like a ring round a finger. Directly underneath each bracket table was a pair of electric terminals, connected by wire conductors with a battery, the wires passing in their circuit through a signal box. This signal box was fitted with a red disc and a green disc, each suspended so as to fall when a current passed. The red disc was in the same circuit with the towing weight bracket; and the green disc was in the same circuit with the time weight bracket. Each of these two circuits was broken at one point only, viz., at the terminal underneath each bracket.

When the towing weight and the time weight descended on their bracket plugs, they knocked them down through their holes into the open space beneath. The plugs were made to a nice easy fit, so that the slightest tap on their upper ends caused them to fall through. In falling through between the electric terminals, the platinum zone of each plug made momentary contact; thus at the moment of passing, and only

ing the electric circuit by closing the termin al
omentary current to liberate and let fall the di sc
ng weight's arrival being thus telegraphed by th e
the time weight's arrival being telegraphed by th e

whether the red or green disc fell first, or bot h
n red fell first, the towing weight bracket wa s
riment repeated. When green fell first, the towin g
et to a higher level, and the experiment repeated.
of the level of the towing weight bracket were mad e
the experiments repeated and re-repeated, until bot h
fell simultaneously. Meanwhile, the level of the tim e
ained unaltered; because that had been fixed before
evel due, by Atwood's law of acceleration, to the tim e
that experiment.

rogressive system of increasing times for each successiv e
, the time predetermined for the first set was 1 secon d,
ct distance the ship would travel, and the towing weig ht
1 second had been ascertained, by the simultaneous fall of
en discs, then that was recorded as one result; and th e
t was lowered for a 2 seconds' descent, and, by a furthe r
and error experiments, the exact travel of the ship in
and in the same way, viz., by the eventually simultaneous
owing weight and time weight on their respective brackets.
lt for 2 seconds being recorded, the results for 3, 4, 5, 6, 7,
seconds were similarly found in consecutive order.

ny of these experiments had been made, and when the
as being prepared, it was thought that two or more observers,
gether the fall of red and green discs in the signal box, might
inion as to whether the fall was absolutely simultaneous or not.
ed that personal error might thus permit an element of doubt
to the results. This fear was set at rest by a refinement of the
gnalling arrangements, the use of which refinement was optional.
ement was effected simply by employing a short wire conductor
t the two brackets, and thus throw what had been two distinct
with one break each into one circuit of two breaks, the breaks
g at the terminals. By this alternative arrangement no current
ass nor disc fall unless the two plugs, in falling through between
minals, made and broke electric contact at the same instants as
other. So by this arrangement it was impossible to obtain any

experimental result at all, unless it were a perfect one. By shipping and unshipping the short connecting wire between the two brackets, this alternative system of signalling could be used or disused at pleasure. In actual practice it was afterwards found that, such is the quickness of the human eye, no disagreement, as to the simultaneousness or non-simultaneousness of the fall, ever arose between various observers of discs when the single circuit system was not employed.

By means of this apparatus, and sundry other dynamometric instruments and appliances which he from time to time invented and superadded, the writer proceeded to explore the principles which govern resisted acceleration; and the bearing of those principles on wave genesis and exodus, and on the behaviour of ships in getting underweigh, and continuing at steady speed, and coming to rest.

Within the compass of one paper of reasonable length to deal with this whole range of enquiry would be impossible. And on the present occasion the writer will confine his remarks to one particular feature of one branch of the extended series of experimental investigations over which he was occupied for a considerable period.

In order to exhibit this particular feature referred to, let B = down-time weight, S = uptime weight, W = towing weight, and D = ship model's displacement weight.

In the course of experimenting, the writer often changed the ratio of B to S and of W to D, ringing the changes, so to speak, in many ways, hoping thus to find what he was in quest of. By laying down the results thus obtained in curves, whose abscissæ were in terms of travel, and whose ordinates were in terms of time, the writer proceeded to compare the curves of the resisted motion of ship model and towing weight to the curves of the comparatively unresisted motion of the time weights. And in both cases the curves proved *parabolic;* thus proving the acceleration in both cases to be *uniform.*

In this comparison, the towing weight, W, is regarded as representing the resisted, and the down-time weight, B, as representing the comparatively unresisted motion.

The resistance of B is mainly due to air opposing the motion of B and S; and the resistance of W is mainly due to water and air opposing the motion of D, and to air opposing the motion of W. If the air resistance be discarded, W may be regarded as resisted (by water) and B as unresisted.

The writer found that when

$$\frac{W}{D} = \frac{B - S}{B + S}$$

the weights W and B, starting simultaneously from the same level, at top of their respective poles, descended side by side at exactly the same rate, and landed at the same instant on their respective brackets, set at the same level at bottom of poles.

This was confirmed by hundreds of experiments; pulley inertia, etc., being eliminated by due allowance.

When the W reached its bracket in many such experiments the D and W had nearly or quite attained their maximum speed.

It will now be necessary to look more closely into this experimental outcome and see what it means.

At the top of two poles (left hand diagram of Plate XIII.), hang two suspended weights, at exactly the same level, side by side, from independent points of support. On burning one leash, which holds both weights stationary, they simultaneously begin to descend.

One of them, B, is opposed in its descent by a resistance—that of the air—so infinitesimal as to be comparatively negligible. But the other of them, W, has, as compared with B, a tremendous resistance, viz., that of the water to the ship in tow.

It will serve to confine the attention to the essentials of this case if it be granted (referring to the companion right hand diagram of Plate XIII.) that one weight, F, is descending through air, while the other weight, R (in this case not towing anything), is descending through water. Say also that the two weights are of lead of the same size and shape as each other, but F having a small cavity within it sufficient to neutralise the difference between air and water displacement weight, so that if the lead weight, F, with the small cavity, were suspended in air over the same frictionless pulley as the solid lead weight, R, suspended in water, each weight would exactly counterbalance the other, as shown by the right hand diagram. Say also that the depth of air beneath and around the F weight, and of water beneath and around the R weight, is unlimited.

It is evident that each weight, R and F, will, under these conditions, fall through its fluid medium at an accelerating rate, until the active resistance of the fluid becomes equal to the force of the falling weight; after which the latter will continue descending at a steady speed.

It is equally evident that the weight falling through air would have to gain a much higher maximum speed than the weight falling through water. For if both weights are of similar size and shape and of equal accelerative force, and, if both resistances being equal to their respective accelerative forces are thus equal to each other, it is plain that, to obtain the given resistance under the given similar conditions,

rather unprofitably) the writer will now endeavour to give a plain ent of the plain answer which Nature herself gave him by the ts of experiments with the apparatus above described.

The answer is this: During the time, = 1, in which the weight in water is reaching its maximum speed = 1, the weight in air moves downward *at the same rate as the weight in water, and likewise reaches speed* = 1; *no more and no less.*

This answer has been invariably given by, not dozens or scores merely, but by hundreds of experiments with ship models in the Wallsend tank, and elsewhere.

Of course the towing weight itself did not actually descend in water while the time weight fell through air, but the experiments were strictly equivalent to that state of things; for having made $\frac{W}{D} = \frac{B - S}{B + S}$, the W and B were endowed at the start with equal accelerative force; and the towing weight, by drawing the ship model through water, raised a resistance so much greater than that of the air that the time weight B and towing weight W did actually in these experiments move downwards, the one with a resistance of mere air, the other with resistance not merely of air but of water also. The latter resistance was such that in some cases the full speed of ships, *i.e.*, the maximum speed of towing weight, was reached, or nearly reached, by the time the weight had fallen to its bracket at the foot of the pole, when the time weight which had started side by side and fallen an equal distance to the towing weight, had covered thereby only a very small fraction of the total descent it would need to make in air before it could attain its maximum speed.

During the first small section of its descent, *i.e.*, so long as it kept exact pace with the towing weight, the time weight (as its parabolic curve of travel and time showed) was travelling with a sensibly uniform acceleration, and as the towing weight kept pace with it up till the expiration of time = 1, when towing weight's speed limit was reached, it was evident that the towing weight's acceleration was sensibly uniform throughout, not merely a small fraction, but the *whole* of its period of acceleration.

From this fact the reasonable inference was that if the descent of the time weight could likewise have been traced throughout its whole period of acceleration till its maximum speed was reached, it would have been seen that its acceleration likewise remained sensibly uniform or constant.

The very numerous experiments made by the writer in this manner left him no room to refuse to believe that (paradoxical as it may at first

blush seem) bodies getting up speeds in fluids, if moved by a constant power, have a constant acceleration.

So long as this constant accelerative force is engaged partly in overcoming the inertia of the fluid mass, and partly in overcoming the inertia of the ship's mass, the latter mass continues to gain speed at a *constant* rate of gain.

Until this great fact was forced on his observation, the writer held the common belief that constant acceleration is the sole privilege, so to speak, of unresisted motion; and that the acceleration of a resisted motion starting at maximum value, in getting up to maximum speed, encountered a continual increase of resistance, and was thereby reduced to zero at the full speed point.

Now, that common belief is true enough so far as it goes. But it is barely the half of the truth, and, unfortunately, when mistaken for the whole truth it leads men to very false practical conclusions. Thus the question arises, what is the other half truth which is not so commonly recognised? We may call the one half K, and the other half P, and the whole C. Then $K = P$, and $K + P = C$.

It may be truly said that this expression is commonly recognised and accepted. And yet, strange to say, it has been thought that this expression, while applying to energy or power, could not be properly applied to speed and time. And, in consequence of the false limitation thus imposed, confusion has resulted.

That a momentary velocity of an increasing or decreasing series of velocities evolving a speed climax, must not be confounded with a full grown speed, has long been insisted on by those who have given this important subject much thought. But the precise relation of any momentary point of the accelerative process, to the complete issue, or climax, of that process, has not yet, so far as the writer's reading informs him, been clearly demonstrated. Meanwhile, failing this necessary demonstration, the common view has obtained that during the getting up of speed by a constant power, the resistance and speed are a series of increasing resistances and increasing speeds possessing a "mean value."

Every one recognises that acceleration and resistance are strictly reciprocal forces. And, hence, if the resistance does increase the acceleration must concurrently decrease.

Many minds have speculated as to whether acceleration in this way decreased uniformly or variably; and if variably by what rule of variation; and much ingenuity has been exercised on attempts to solve this last occult problem.

Upon these important points the writer's mind was ultimately set at rest by the fact, so plainly revealed by the Wallsend tank experiments, that acceleration in such cases does not decrease at all. That is to say, a ship under constant power does not gain her full speed by decreasing, or in any way varying, but by constant increments.

These experiments admit of no other rational conclusion than that each of the functions of motion—power, speed, and time—possesses a latent as well as an active value; and that at any moment of motion the true value can only be found by adding together the latent and active values present at that moment.

At the initial moment of the process of acceleration the maximum latent value of resistance and time and speed co-exists with the maximum active value of accelerative force. At the final moment of acceleration the minimum or zero active value of propulsive force co-exists with the maximum active value of resistance, time, and speed. And at any moment intermediate between these two extremes the active value of any function of the motion, added to its latent value, equals the maximum value which is constant throughout the whole process.

To treat of these functions as if their active value present at any moment were their whole value at that moment, and to ignore the latent value as though it were of no value, must induce serious mistakes of estimate in valuations of motion.

A clear understanding of the unity and constancy of value present throughout any motion produced by a constant power, forbids absolutely that false method of measuring which credits accelerating speed and resistance with the possession of "mean values." It is true their active and latent values both vary throughout the process of speed-development, and thus there may be rightly estimated a mean K, or a mean P, value. But the practically effective constant value is at every instant the P and the K value added together.

It follows from the above-named facts and principles experimentally attested that two ships of equal $\frac{W}{D}$ ratio, or of equal displacement and power, the one bluff and the other fine, will go, during the whole time that the bluff ship is gaining speed, at exactly equal rate. But after the bluff ship has won her speed the fine ship still continues to gather speed; and so from (and not before) the moment when the bluff vessel's maximum speed is first obtained the fine vessel goes on forging ahead until she in turn shall have attained her maximum speed.

In conclusion, the writer regrets that while dwelling on that feature of his experimental investigation which reveals that the acceleration of ships under constant power is uniform, he has not been able to dwell also on the remarkable fact, revealed no less clearly by the same series of experiments, that when W = towing weight, and D = ship's displacement, the value of the constant acceleration is not $= \frac{W}{D + W} g$, but is $= \frac{W}{D} g$.

In this last named fact is couched a rich mine of hydrodynamic truth, which cannot be displayed to any adequate degree at the tail end of this paper. The writer hopes, however, on some future occasion to present this fact in some of its many important and most interesting bearings on the speed behaviour of ships.

The discussion was postponed, and the meeting adjourned.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

ELEVENTH SESSION, 1894-95.

PROCEEDINGS.

FOURTH GENERAL MEETING OF THE SESSION HELD IN THE LECTURE HALL OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-UPON-TYNE, ON TUESDAY EVENING, JANUARY 15TH, 1895.

ALDERMAN THOMAS RICHARDSON, B.A., J.P., PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, held in Sunderland, on December 19th, 1894, which were approved by the members present, and signed by the President.

The ballot for new members having been taken, the President appointed Messrs. W. C. Mountain and M. Sandison to examine the voting papers, and the following gentlemen were declared elected:—

MEMBERS.

Lie, Gotfred, Superintendent Engineer, Det Bergenske Dampskibsselskab, Bergen.
O'Halloran, Timothy, Engineer, 205, Avenue du Commerce, Antwerp, Belgium.
Wray, Thomas W., Surveyor to Board of Trade, Board of Trade Offices, North Shields.

GRADUATES.

Patterson, Robert O., Apprentice Engineer, Thorneyholme, Blaydon-on-Tyne.
Scott, Alex. C., Apprentice Engineer, Norwood House, Heaton, Newcastle-upon-Tyne.

REPRESENTATION AT LLOYD'S.

The PRESIDENT announced that the Council had re-elected Messrs. William Boyd, F. C. Marshall, R. Thompson, and H. Withy to serve on the Sub-Committee of Lloyd's Register of Shipping as representing the engineers and shipbuilders of the North-East Coast for a further term of four years.

AWARDS TO GRADUATES.

The PRESIDENT also announced that the Council had awarded the first prize for papers read before the Graduates' Section during the tenth session of the Institution to Mr. Andrew Young, the prize paper being "Notes on the Launching of Vessels." The second prize to be divided between Mr. W. Oxton for his paper on "A few Points of Interest concerning Pumping Arrangements," and Mr. A. L. Forster, for his paper on "Some Points in High Speed Engines." No gold medals were awarded for the papers read last year before the general body of the Institution.

Mr. ANDREW YOUNG replied to the discussion on his paper entitled "A Brief Outline of the Theory of the Rolling of Ships."

The discussion on Mr. Caws's paper on "An Account of some Experimental Studies of Ship Acceleration and Fluid Resistance" was opened.

Mr. W. C. MOUNTAIN read a paper on "The Design and Efficiency of Plant for the Transmission of Power by Electricity."

REPLY TO THE DISCUSSION ON MR. ANDREW YOUNG'S PAPER ON "A BRIEF OUTLINE OF THE THEORY OF THE ROLLING OF SHIPS."

Mr. ANDREW YOUNG, replying to the discussion on his paper, said he had to thank those gentlemen who did him the honour of reading his paper, when as yet it was a Graduate production, and considered it of sufficient interest and value to lay before the senior section of the Institution. He had also to thank those members who, in the discussion, expressed their appreciation of his labours. In opening the discussion, Mr. Sivewright stated that at one time he had consulted many papers on the rolling of ships, but had found that the questions of proportions and stowage of cargo were not included in these investigations. Now, he thought if Mr. Sivewright examined them more closely he would find that both Froude and Bertin dealt with these matters very fully; indeed, any investigation in which they were neglected would be practically useless. Froude's equation for the angle of deviation involved the still water period, which, of course, depended upon the metacentric height and moment of inertia; the effect of resistance which was partly dependent on the vessel's form was also included as explained in his paper. Mr. Sivewright's objection to bilge keels was only based upon their additional skin friction, but a simple calculation would show that for an ordinary cargo vessel the horse-power required to overcome this would be very trifling if the plane of the bilge keel, as pointed out by Mr. Thompson, was suitably disposed, *i.e.*, diagonally, so as to produce a diagonal line on the shell, which was regarded by Prof. Rankine as the path of a particle of water during its passage past the ship. He was certain that any reduction in speed on account of bilge keels was quite inappreciable. Mr. Fothergill raised a question as to what size the bilge keel for a given ship should be. No definite rule could be given for the breadth, or rather the resisting area; for it was a question of disposing this area to most advantage, *i.e.*, as far as possible from the axis of oscillation, so that a short broad keel on the bilge would be more efficient than a long narrow one extended beyond the bilge. In practice the breadth was necessarily limited by the considerations referred to by Mr. De Rusett, and he could not understand why, if they were kept within the rise of floor line and moulded breadth line, they should prove a source of danger, an opinion held by Mr. Fothergill and also Mr. Sivewright. Summing up the remarks of the speakers on this matter, the balance of the testimony appeared to be in favour of keels, and this result of experience,

f which the case cited by Mr. De Rusett of the clincher-built tug and fishing cobles afforded an interesting illustration, was thoroughly corroborated by theoretical and experimental enquiries, which showed that to increase the moment of resistance was the surest method of preventing increase in amplitude of roll. The method proposed by Mr. Hill, for diminishing the stiffness of a ship, was certainly bound to be very effective, and had the advantage of securing additional propeller immersion. Its adoption must prove beneficial in easing her motions and tend to less frequency of coperiodicity. Yet he would here emphasise what was brought out in the paper; that, although these qualities might be secured by increasing the moment of inertia, yet the capacity for energy was thereby increased; and consequently when once the ship was on the swing, so to speak, the resistance of the water would have less effect in preventing increase of amplitude; and the more so in a slow moving light ship, as clearly brought out by Mr. Hök, in which the moment of resistance was small on account of her comparatively shallow draughts. He did not mean to say that this would be an objection to the adoption of the tank in the ship instanced by Mr. Hill, for her remaining 65 inches of metacentric height was ample—perhaps too much—under the circumstances. He thought it might be of interest in connection with this subject if Mr. Hill would kindly favour them with her captain's opinion of her behaviour with the tank full, as compared with the empty condition. He was quite prepared to admit with Mr. Hök that objections, of which he stated the principal, might be urged against the assumptions made in the theory as it stood at present—assumptions and limitations which were fully recognised by its propounder. But though admitting these imperfections and acknowledging the authority of M. Bertin, from whose recent paper Mr. Hök quoted, he felt certain (only, however, from what he had been enabled to read of the matter) that their knowledge of the subject had been considerably advanced, but might require further experimental verification to obtain a more general acceptance. He considered that the design and arrangement of 14,000 tons of fighting material as worked into a first-class battle ship could not be proceeded with with the same degree of confidence as to behaviour at sea if the designer were in complete ignorance of the principles, with their results as elucidated by Mr. Froude. He now desired to express his thanks to the Institution for the courteous attention which had been given to his paper.

A vote of thanks was accorded by acclamation to Mr. Young for his paper.

DISCUSSION ON MR. CAWS'S PAPER ON "SHIP ACCELERATION AND FLUID RESISTANCE."

The following communications were read by the SECRETARY :—

LONDON,

DEAR MR. DUCKITT, *January 14th*, 1895.

I am sure that all who have listened to, or read, the paper by Mr. Frank Caws upon "Fluid Resistance," must be impressed by the ingenuity and patience which he has brought to bear upon the experiments performed by him.

The subject he has been investigating is, both in theory and practice, an extremely difficult one to analyse with any great degree of accuracy, but Mr. Caws has given us what he considers an absolute and unerring result.

In model experiment it is very necessary to be accurate in our measurements, since for example the gross I.H.P. of a 405 foot ship is generally 9 or 10 millions of times as great as the net I.H.P. of a 5 foot model; so that any error brought into the model experiment is liable to be multiplied by a considerable amount when transformed into practice.

The gist of Mr. Caws's paper, as I understand it, is to state that after any given interval of time, while getting underweigh, the velocity of a model of given displacement and power is independent of the shape of the model until the maximum speed due to the power is attained. This statement implies that the difference in the amount of the mass of water that has to be set in motion by a full ship and a fine ship respectively does not affect the performance until the fuller vessel has reached her full speed. It implies that a vessel towed broadside on will start as easily, and at first make way as rapidly as one towed in the usual manner, notwithstanding the difference in the wave-masses set in motion in the two cases.

The statement is a somewhat startling one, but based, it seems to me, upon insufficient data. The possibility that "errors of observation" may account for something claims consideration; and when it is borne in mind that the whole fluid resistance due to a 10 foot model of a 240 foot ship at speed corresponding to 9 knots, would, if doubled, only affect the accelerative run by about the 100th part of a second, one can easily see how in making allowance for inertia of pulleys, towlines, etc., an error of minute amount, but of important influence, could be introduced into the calculations.

The inertia of the models, weights, and pulleys, as well as friction of air and bearings, all tend to overshadow, as it were, the real quantity sought after, which is like a speck of gold in a mass of quarts, and it seems as if in this case some of the gold had been lost with the quartz.

Yours faithfully,

J. DENHOLM YOUNG.

SUNDERLAND,

DEAR MR. DUCKITT, *January 14th*, 1895.

I think we are greatly indebted to Mr. Caws for this paper, for he has been good enough to give us an insight into the train of reasoning by which he arrived at the fallacy on which his extraordinary laws of motion, propounded in his previous paper, and his experimental tank are based.

When I listened to his previous paper I was at a loss to understand, not what his laws of motion were, for they were stated plainly enough, but how he had discovered them. However, this paper, which certainly ought to have preceded his first paper, gives us the clue, and for this we owe him a debt of gratitude.

To explain the trap into which Mr. Caws has fallen, and which resulted in the creation of his laws of motion and his experimental tank, I shall deal with the question which he asks himself on page 97 : "Now, how far will this similar other weight, F, fall through air in time = 1 while the weight R is falling through water, the vertical distance = 1?"

About two hundred years ago anyone well conversant with dynamics could have answered this question. It will be well-known to many in this room that Newton not only discovered the theory of the motion of bodies falling in fluids, but also amply verified his theory by numerous experiments. But, for the benefit of those who may not be conversant with Newton's labours in this matter, I may be permitted to give a brief outline of them, at least so much as has any direct bearing on this paper.

Newton verified his theory by letting fall globes of different densities and diameters in air and water. From these experiments he discovered, 1st, that the resistances varied as the densities of the fluids; 2nd, that the acceleration was *not* uniform, but decreasing, first very slowly, then more rapidly, and then very slowly again, until it became *nil*, when the falling body had attained uniform speed; and 3rd, that the resisted motion was *not* parabolic, as in the case of unresisted motion, but logarithmic.

In order to show the results of his investigation graphically, I have prepared the appended diagram (Plate XIV.). Curve A represents the velocity in resisted motion, which, when uniform, attains the value 1. Curve B is the space described by the unresisted body, and curve C is that of the resisted body.

Now, according to Mr. Caws, the acceleration is a constant quantity throughout, and the unresisted and resisted bodies fall through equal spaces until the resisted body attains its maximum speed. From this it follows that curve A should be a straight line, and curves B and C coincide. My diagram shows how very far this is from the actual truth. If you look at the curves appended you will find that up to a certain time interval, say eight-tenths, the velocity curve A is practically a straight line, and the space-curves B and C practically coincide, but that after this time interval the velocity curve A departs considerably from a straight line, and gradually attains its maximum value = 1, and the space curves B and C diverge more and more.

Everybody will now understand how Mr. Caws has been deceived. Simply by imagining that the full speed condition of his model was established long before it ever occurred. You will find from the sketch in Mr. Caws's paper that his model travelled about twice her own length, and this length he deemed sufficient for attaining full speed. Now, Newton's globes fell from ten to twenty times their diameter before attaining anything like full speed, and I have made numerous experiments on this point in the tank kindly erected for me by Mr. Laing, and I find that a run, not of two, not even of four or six times the length of the model, suffices for attaining full speed, and this fact is plainly visible to the naked eye without any special instrument for discovering it whatever.

So it may be accepted as perfectly certain that Mr. Caws has unfortunately experimented on only that part of the motion where the velocity curve is approximately straight, and the space curve in resisted and unresisted motion practically coincide, and has in this way been lamentably deceived. And yet this is very strange, for one can very well read between the lines that Mr. Caws himself was very much in doubt whether his models really attained full speed or not. For in one part of the paper he writes: "And in *many* such experiments the D and W had nearly or quite attained their maximum speed;" and in another place, "In *some* cases the full speed of ships was reached or nearly reached." Well, at the time interval eight-tenths, above which it is probable that Mr. Caws did not experiment, the speed of Newton's globes was only two-thirds of their maximum speed, and they required to travel a distance fifteen times as

great to attain their maximum speed, and the time occupied was about six times as long as for two-third speed. Newton found also that in the time eight-tenths the globes in vacuum and in water fell practically the same distance, and that when the approximate maximum speed was attained the weight in vacuum had fallen three times the distance of the weight in water. These data serve to show that Mr. Caws would require a much longer run in his tank (in proportion to model) to establish the complete motion of falling bodies in liquids, and this is corroborated by my own experience, which is that even when the model has run six times her own length it is plainly visible to the naked eye that she is still gathering speed.

To come to other matters, it seems to me that the motion of a body on the surface of the water must be essentially different to that of a body falling through the water. So I do think that it is not safe to assume that results obtained from accelerating floating models are strictly applicable to bodies falling in the fluid.

Apart from this, Mr. Caws's apparatus had several defects, such as the inconstancy of the towing force due to the lower pulley *p* being raised so high above the level of the model to prevent the towing line from sagging into the water when the model was first set off. I can well imagine the whole motion. When the model was liberated she went off very quickly on account of immediate sagging taking place in the lines D *p* and *p* whereas the motive weight W would at first hardly descend at all. After this the sagging would get less and less, due to increased resistance, until the lines were perhaps practically straight again. And you will readily understand that on account of this interference of the towing lines with the motion, and on account of the inconstancy of the motive force, the method of experimenting could not furnish very reliable data.

I hope to have sufficiently shown how this unfortunate theory has developed. And if my remarks, which have been made from a sense of duty, will have the effect of making Mr. Caws abandon the laws of motion on which his experimental tank is based, they will have served a useful purpose.

Yours faithfully,

W. H

Mr. Andrew Young said the net results of Mr. Caws's experim as far as he could make out from his paper, appeared to be that w velocity of the model in the tank was gradually increasing f increase was taking place at a uniform rate; o constant. This result necessarily i

the force, acting upon the model or weight, was constant; at which, he must admit, he was rather astonished. For what were the forces acting at any instant on the weight whose motion they were considering? Simply gravity, the resistance which the model encountered, and the frictional resistance of the apparatus itself. Now, according to strict dynamical law, the acceleration, which was the visible effect of the forces acting upon a body was proportional to these forces. If it were the case, as Mr. Caws maintained, that the acceleration was constant, then, omitting friction of the apparatus, the two other forces, gravity and model resistance, must be constant at every instant; but the instantaneous velocity of the model was varying from point to point, and it was difficult to believe that the resistance remained constant under these circumstances, and did not produce a corresponding effect upon the acceleration. So he (Mr. Young) was disposed to suspect that there had been some slight imperfection in observation or analysis of the results, which had failed to give a result more in harmony with what theoretical considerations would lead them to expect. He must take this opportunity of frankly saying that he considered Mr. Caws's views as to the extension of the use of the terms "potential" and "kinetic" to force and motion was most confusing and really of no value. They did not require such phrases as "kinetic" and "potential" motion, indeed they were meaningless. The description of the experiment which occupied the first part of the paper was in itself interesting; but he did not think that the analogy or illustration the author brought forward of the motion of bodies falling in air and water had given them any clue to the method he adopted for measuring the resistance of the model in the tank at a given speed, which was really what they wanted to know. There was much, also, in the paper which might not be very clear to those unacquainted with the writer's system of dynamics. He thought it might be interesting, perhaps, to have a fuller discussion of the remarkable equation $C = K + P$, in which $K = P =$ half truth and $C =$ whole truth. This appears somewhat axiomatic. There might, however, be a hidden meaning in it which was not quite apparent. He should like to know the distinction between a full grown speed and a speed climax, and why the author assumed that everyone admitted acceleration and resistance to be reciprocal *forces*. Resistance he recognised to be a force, inasmuch as it affected motion; but he always understood that acceleration meant change of velocity. Now, this might appear a little hypercritical, but he did not think that these points should be allowed to pass unnoticed. He valued and appreciated

Mr. Caws's endeavours to bring the experimental study of ship resistance within the reach of every shipbuilder interested in the matter, and he (Mr. Young) ventured to express a belief that the method here described might, if the results were properly analysed, be made to yield more fruit than the pendulum meters which Mr. Caws employed at Sunderland. Last year he had the privilege, through the courtesy of its inventor, of witnessing an experiment made there, and it occurred to him that the whole object of the experiment was to measure accurately the acceleration when the model was passing through the vertex of the pendulum under the action of a given motive force, and at a known velocity. He considered that this might be done by means of a falling weight whose motion, and thus velocity might be automatically recorded by a method such as employed by Morin in connection with Atwood's machine, the velocity or $\frac{ds}{dt}$ being found by drawing tangents to the space-time curve. If the value of these tangents be plotted as ordinates to a new curve, the tangents to this new curve would give a measure of $\frac{d^2s}{dt^2}$, *i.e.*, the acceleration to which the resultant force acting on the body was proportional. Now, the acceleration due to gravity acting on the weight was constant, and that due to the frictional resistance of the apparatus might be found separately by experiment, so that the remainder would represent that due to the resistance of the model which may thus be obtained at any speed given by the curve of $\frac{ds}{dt}$. He feared, however, that the precision required for the observations and tangent-drawing might prove, in actual experiment, to be rather a serious obstacle to the success of such a method.

Mr. Caws's reply to the discussion was deferred.

THE DESIGN AND EFFICIENCY OF PLANT FOR THE TRANSMISSION OF POWER BY ELECTRICITY.

By W. C. MOUNTAIN, Member of Council.

[Read before the Institution, in Newcastle-upon-Tyne, on January 15th, 1895.]

The writer of this paper proposes to generally describe the system of carrying out a transmission of power plant by electricity, and to do this thoroughly it is necessary to commence the subject from the beginning, and to describe the various units used by electrical engineers, and their application to the subject.

The practical units, which correspond to the pressure and foot-pounds, as used by engineers, are the volt, the ampère, the ohm, and the watt.

The volt, the unit of electro-motive force or pressure, is usually written E.M.F. The legal volt is the electro-motive force which maintains a current of 1 ampère in a conductor whose resistance is the legal ohm. In speaking of volts or E.M.F., the electrical engineer uses this term in the same way that an engineer, accustomed to steam practice, uses pounds pressure per square inch, and when he speaks of a machine giving an E.M.F. of so many volts he means that the machine gives an electrical pressure which, to an engineer, conveys the idea of so many pounds pressure per square inch.

The volt is equal to one hundred million (100,000,000) C.G.S. units of E.M.F., or about 7 per cent. less than the E.M.F. of a standard Daniells cell (the E.M.F. of a standard Daniells cell being about 1·1 volts), which is, as is well known, a primary battery consisting of copper and zinc elements, the copper being immersed in a solution of sulphate of copper, and the zinc in a solution of sulphuric acid and water, the two elements being divided by a porous pot.

E.M.F. is equivalent to the difference of potential between two points.

The ampère, the unit of current, is described practically as that amount of current which decomposes ·00009324 gramme of water per second, or deposits 4·025 grammes of silver per hour. 386·4 ampères will deposit 1 lb. of copper per hour.

The ohm is the unit of resistance, and is equal to the resistance of a column of pure mercury 1 square millimetre in section and 106 centimetres long, at a temperature of melting ice.

To still further convey the meaning of these units, and provide for a practical way of applying them, a further unit, the watt, is used, the watt being equal to one volt-ampère. A watt or volt-ampère represents the amount of work done by the dynamo or generator in a second; and assuming that a dynamo is giving a current of 100 ampères at an E.M.F. or pressure of 100 volts, these multiplied together equal 10,000 volt-ampères or watts, total output of the machine. 746 watts or volt-ampères are equal to one electrical horse-power, and correspond to the 33,000 foot-pounds per minute used in engineering as the standard horse-power. Therefore in order to ascertain the horse-power required to drive a dynamo to any given capacity, the total number of watts have to be divided by 746, which gives the electrical horse-power generated. Of course as no dynamo is capable of giving out the whole of the power put into it, the electrical and commercial efficiency of the machine has to be taken into consideration, but as good dynamos of reasonable size are capable of converting 96 per cent. of the actual power put into them into electrical energy, and also as the total commercial efficiency of good machines is as high as 90 to 93 per cent., and in some cases slightly higher, it follows that the formula for working out the actual power required to drive a dynamo giving 100 ampères at 100 volts is, assuming the efficiency at 90 per cent.,

$$\frac{10{,}000 \times 100}{746 \times 90} = 14{\cdot}89,$$

say, 15 horse-power on the dynamo pulley for a dynamo generating 10,000 watts, or what is known as a 10 unit machine.

This power is usually described as brake or effective horse-power, and of course the indicated horse-power necessary to produce a given brake horse-power varies in different makes of engines, but assuming that the brake horse-power of an engine—to be on the safe side—is 75 per cent. in small engines, in larger engines the efficiency is considerably greater, and reaches in many cases as much as 90 per cent. of the total indicated horse-power; an allowance equal to this has to be made between the brake horse-power and the indicated power in estimating the size and power of the engine required.

Having described the units used in the practical application of electricity to lighting or to motive power purposes, a short description of a dynamo and electric motor is necessary, and in order to clearly

explain the construction of a dynamo and electric motor the diagram on Plate XV. is given.

On reference to this diagram it will be noted that the revolving portion placed between the field magnets, which is called the armature, is marked A. The armature core is composed of charcoal iron discs, mounted upon gun-metal driving horns, and secured firmly to the spindle; the armature conductors are wound upon the periphery of the core, and in these conductors the E.M.F. and current are generated.

C represents the commutator, which is usually constructed of hard drawn copper segments insulated with mica, and mounted upon a sleeve, there being several methods of securing the sections to the sleeve, but the one represented, viz., by V's, is extremely satisfactory in practice. The armature and commutator are mounted upon the spindle marked S, which runs in the bearings, and it is advisable in all dynamos that these bearings should be adjustable, and fitted with means of perfect lubrication.

The letters F M represent the field magnets, and in the particular diagram shown the field magnets are represented as being of the horseshoe type, with the coils placed above the armature. It is always advisable to place the coils above the armature if possible, as it prevents any possibility of oil getting upon them whilst running. In order to obtain a high efficiency in the machine it is necessary to make the field magnets of a massive section. This also has the effect of causing the machine to work without sparking, assuming the armature to be suitably proportioned.

F M C represents the field magnet coils, which should in all cases be wound upon independent bobbins, so that they can be removed from the machine for repairs if necessary.

The end view of the machine, shown in Plate XVI., represents the brush connections and the method of collecting the current from the commutator and conveying it to the terminals. It will be understood that the current is generated in the armature, and flows from the armature connections to the commutator sections, and is there collected by the brushes.

An electric motor is an exact counterpart of a dynamo, and the laws which govern the design of first-class dynamos apply equally to the design of electric motors, and it is very often a matter of convenience in ordering transmission of power plants, where one dynamo and one motor are used, to have the machines constructed identically as regards the armature, because it necessitates but one spare armature, which will fit either machine when required.

When the armature is made to revolve by a belt or steam engine coupled direct, the armature wires cut the weak lines of magnetism which

remain in the field magnets, the magnets of course being made of eithe soft steel or wrought iron. A weak E.M.F. is set up in the armature, an this sends a slight current through either the shunt or series windings, wit the result that the strength of the magnets is slightly increased, this agai increases the E.M.F., and on the machine attaining its full speed th magnets are quickly magnetised to saturation by the current flowin round them from the armature, and the full E.M.F. of the machine then obtained.

It follows that if a current of electricity is sent round the fie magnets and also through the armature of a similar machine, that a action is set up and the armature begins to revolve and quickly runs a speed corresponding to the speed of the dynamo, assuming that windings are suitably proportioned.

In order to explain this clearly a dynamo and motor identically co structed are exhibited. It being impossible to drive the dynamo, the fi machine is therefore driven as a motor by a current of electricity obtaine on the premises. This causes the machine to revolve and it drives b belt on to the second machine, which in this case is a dynamo, produce a current of electricity lighting incandescent lamps as exhibited.

A well constructed dynamo has the important property of being practically self-regulating, that is to say, that the machine absorbs powe to drive it exactly in proportion to the output it is called upon to give and does not take, as is generally supposed, the same amount of power t drive whatever its output may be. It would involve a very length explanation to describe exactly why this takes place, but probably th simple statement that a dynamo is a machine generating an electric motive force, and that this force drives the current through the motor c lamps in accordance with the resistance opposed, generally describes wha takes place. As an example, we will assume that a dynamo is supplyin current to one motor, its normal electro-motive force is 100 volts, an that the resistance offered by the motor and its circuit is 10 ohm it follows that a current of 10 ampères will flow through the motor givin approximately $\frac{3}{4}$ of a horse-power on the motor; if another motor i switched on into circuit then another path with a resistance of 1 ohms is opened for the current and 10 ampères flow through this path and so on until the whole capacity of the machine is taken up, the limi of current which the machine will give being decided by the sectiona area of the conductors on the armature and field magnets and also th sparking of the machine, because if a machine is too heavily loaded th armature and field magnets will heat and the machine will spark badly.

A motor has very similar properties to a dynamo, and will give power in proportion to the current that is passing through it, but assuming that too much work is taken out of the motor then the machine will start heating and sparking, owing to the current through the armature and magnets being too great.

From the above it will be seen that for all transmission of power plants it is advisable to have the motors well above their work, and the bulk of the failures in electric transmission of power plants which are heard of from time to time arise purely from the fact that motors far too small for the work are used. If a purchaser wishes to put down a steam engine he usually buys an engine well above its work, but if he buys a motor he generally specifies a machine capable of just doing the work required with no margin whatever. A steam engine will struggle on if heavily loaded, and if the load is altogether too great will stop, no great harm happening, but an electric motor will struggle on and finally burn up.

Having described the dynamo, the next thing to be considered, before coming to the actual question of designing an electrical transmission of power plant, are the cables, and for future reference the table on the next page is given of sizes, sectional areas, carrying capacity at a density of 1,000 ampères per square inch, and resistance in ohms per statute mile.

In laying down a transmission of power or lighting plant it is necessary to consider the loss of watts and volts in a cable, as it is very often necessary to proportion the size of the cable so that a certain number of watts or volts are lost, and the following rules will be of service :—

Rules to Find the Loss in Volts in a Cable.—The volts lost in a cable of any length may be found by multiplying the resistance of the cable by the current flowing. It must, of course, be remembered in making this calculation that the distance between the dynamo and motor is doubled in the cable on account of the return conductor; if, therefore, the motor is half a mile from the dynamo, the total length of cable will be one mile.

EXAMPLE.

To find the loss of volts in a 7/15 cable, that is, a cable composed of seven wires, No. 15 L.S.G., 1 mile in length, with a current of 29 ampères (*i.e.*, approximately 1,000 ampères per square inch section of copper) resistance of 1 mile of 7/15 cable equals 1·498 ohms.

$$1{\cdot}498 \times 29 \text{ ampères} = 43{\cdot}442 \text{ volts lost.}$$

It may be taken as a general rule (sufficiently accurate for ordinary practice) that there is a loss of approximately 2½ volts per 100 yards in cables where the current density is 1,000 ampères per square inch section of copper.

Particulars of Conductors.

Legal Standard Gauge.	Diameter of each Wire.		Diameter of the Strand.		Sectional Area.		Weight.	Resistance.	Ca Ca
	Inches.	m/m	Inches.	m/m	Sq. Inches.	Sq. m/m	Per Mile in Lbs.	Ohms.	An
7/22	·028	·711	·084	2·13	·0044	2·838	90	9·908	
7/21	·032	·813	·096	2·44	·0057	3·703	117	7·596	
7/20	·036	·914	·108	2·74	·0072	4·690	148	5·998	
7/19	·040	1·02	·120	3·04	·0089	5·786	183	4·861	
7/18	·048	1·22	·144	3·66	·0129	8·321	263	3·380	
7/17	·056	1·42	·168	4·27	·0176	11·35	358	2·477	
7/16	·064	1·62	·192	4·88	·0230	14·83	468	1·895	
7/15	·072	1·83	·216	5·49	·0291	18·77	592	1·498	
7/14	·080	2·03	·240	6·10	·0359	23·16	731	1·214	
7/13	·092	2·34	·276	7·01	·0475	30·64	967	·9179	
7/12	·104	2·64	·312	7·93	·0607	39·16	1235	·7183	
7/11	·116	2·94	·348	8·84	·0755	48·70	1537	·5776	
7/10	·128	3·25	·384	9·75	·0919	59·28	1870	·4744	
19/22	·028	·711	·140	3·56	·0120	7·741	244	3·634	
19/21	·032	·813	·160	4·07	·0156	10·06	318	2·795	
19/20	·036	·914	·180	4·57	·0198	12·77	403	2·202	
19/19	·040	1·02	·200	5·08	·0244	15·74	497	1·786	
19/18	·048	1·22	·240	6·10	·0351	22 64	714	1·243	
19/17	·056	1·42	·280	7·11	·0479	30·90	975	·9103	
19/16	·064	1·62	·320	8·13	·0625	40·32	1272	·6976	
19/15	·072	1·83	·360	9·14	·0791	51·03	1610	·5512	
19/14	·080	2·03	·400	10·16	·0976	62·96	1987	·4467	
19/13	·092	2·34	·460	11·68	·129	83·22	2625	·3380	1
19/12	·104	2·64	·520	13·22	·165	106·4	3358	·2642	1
19/11	·116	2·94	·580	14·73	·205	132·2	4173	·2126	2
19/10	·128	3·25	·640	16·26	·250	161·2	5090	·1744	2
37/19	·040	1·02	·280	7·11	·0477	30·77	971	·9140	
37/18	·048	1·22	·336	8·53	·0686	44·25	1396	·6355	
37/17	·056	1·42	·392	9·96	·0934	60·25	1901	·4667	
37/16	·064	1·62	·448	11·38	·122	80·70	2483	·3574	1
37/15	·072	1·83	·504	12·80	·154	99·35	3134	·2831	1
37/14	·080	2·03	·560	14·22	·191	123·2	3887	·2283	1
37/13	·092	2·34	·644	16·36	·252	162·5	5129	·1730	2
37/12	·104	2·64	·728	18 49	·322	208	6554	·1354	3
37/11	·116	2·94	·812	20·63	·401	259	8160	·1087	4
37/10	·128	3·25	·896	22·76	·488	315	9931	·0893	4
61/18	·048	1·22	·432	10·97	·113	73·00	2300	·3859	1
61/17	·056	1·42	·504	12·80	·154	99·35	3134	·2831	1
61/16	·064	1·62	·576	14·63	·201	129·6	4091	·2169	2
61/15	·072	1·83	·648	16·46	·255	164·5	5189	·1710	2
61/14	·080	2·03	·720	18·29	·315	203	6410	·1384	3
61/13	·092	2·34	·828	21·03	·416	268	8467	·1048	4
61/12	·104	2·64	·936	23·77	·532	343	10820	·0819	5
61/11	·116	2·94	1·044	26·52	·661	426	13450	·0659	6
61/10	·128	3·25	1·152	29·26	·805	519	16390	·0541	8

Rule to Find Loss in Watts or Volt-ampères in a Cable.—A further rule, which will be of service in calculating the watts lost in any length of cable, is the following:—First, square the current—*i.e.*, multiply the current flowing in ampères by itself, and then multiply by the resistance, which will give the Watts lost in the cable. For instance:—

Example.

To find the watts lost in a 7/15 cable when carrying a current of 29 ampères. 29 × 29 ampères × 1·498 ohms = 1,259·811 watts lost.

It is therefore necessary, in estimating the size of generator required to drive a motor, to add to the actual watts required at the motor terminals the watts lost in the cables, and also the generator must be constructed to give at its terminals an E.M.F. equal to the volts lost in the cables, plus the volts required at the terminals of the motor. By suitably proportioning the size of cable to the work to be done it is possible to make the power consumed in the cables anything that may be desired, but it must be borne in mind that by unreasonably increasing the size of the cable, and thus reducing the loss, a point is soon reached by which the first cost of the cable will be so high that the saving will not be economical.

Class of Cables.

There are, of course, many descriptions of cables suitable for transmission of power work—*i.e.*, as regards the insulating substance, but the writer does not recommend that any cable should be used with an insulation resistance of less than 300 megohms per statute mile. This is a suitable insulation for all voltages up to, say, 200; exceeding 200 and up to 600 the insulation resistance of the cables should be not less than 600 megohms per statute mile; and for a higher voltage, particularly if there is any damp, the insulation resistance should be not less than 2,000 megohms per statute mile.

A megohm it may be here mentioned is the resistance equal to one million ohms, and the resistance of a cable is usually taken by immersing it in salt water for 24 hours, and then taking the insulation resistance between the conductor and the earth.

Various classes of insulating materials are used for the insulation of cables as under:—

1. Pure india-rubber.
2. Vulcanized india-rubber.
3. Vulcanized bitumen.
4. Bituminized fibre.
5. Paper.

Other substances have been used with more or less success, but the above may be taken to fairly represent the standard substances in use.

For lightly insulated cables pure india-rubber is sometimes used, but for general work the writer does not recommend this class of insulation, and strongly advises that vulcanized india-rubber be adopted. Bitumen is largely used for colliery work, but cables of this description are generally armoured with galvanized iron wire or steel tape, and the writer would not recommend the use of bituminized covered cables except when a protection of this class is used.

Cables insulated with bituminized fibre are also largely used for transmission plants, and Mr. Siemens in his paper before the Mining Institute showed a class of cable of this description which he used throughout his works.

Bituminized fibre is necessarily a substance which would very quickly absorb damp, and may be described as a mechanical insulating material, as it will mechanically stand a considerable amount of knocking about, and is only a thorougly good insulating material when dry; it has therefore to be protected by being drawn into a lead pipe, and may be then either braided or compounded outside the lead or, as is most usual, armoured with galvanized iron wires or steel tape. The paper insulation has practically the same properties as the bituminized fibre, and must be protected with lead, and if liable to injury must be further protected by galvanized iron wires or steel tape.

If it is proposed to run the cables along a workshop, in casing, or to secure them by cleats or support them on insulators, then cables insulated with vulcanized india-rubber, or even pure india-rubber in very dry places can be successfully used, but if it is desired to lay the cables underground, then they should either be lead covered, or preferably lead covered and armoured. Where cables are liable to mechanical injury, *i.e.*, in an engine shop or a colliery, it is advisable to have them further protected by galvanized iron wires or steel tapes, and the cables are generally further protected by a thick covering of hemp coated with preservative compound. It is advisable also to run the cables in wood casing, the casing to be grooved and fitted with a cover.

Efficiency of Motors.

Before any general scheme can be laid down, and also before the output of the dynamo can be calculated it is necessary to take the actual watts required at the motor terminals. and to add to this the watts lost in the cables themselves conveying the current from the dynamo to the

tors, and the following table is given, showing the approximate ciencies of electrical motors of varying horse-powers, with the watts uired at the terminals of the motors at the efficiencies given, to proce one effective horse-power on the motor shaft.

Effective Horse-power of Motor.	Commercial Efficiency. Per Cent.	Watts per Horse-power required at Terminals.
50 and upwards ...	90	829
40	88	848
25	85	878
15	80	904
5	75	995
3	70	1,066
1	65	1,148
½	60	1,244
¼	55	1,357
⅛	50	1,492

As an example let it be assumed that it is intended to drive a motor 440 yards away from the dynamo, *i.e.*, a quarter of a mile, and the motor is to give 25 effective horse-power, with an efficiency of 85 per cent, the formula there is as under :—

25 effective horse-power × 878 watts per horse-power = 21,950 watts at motor terminals.

The voltage at which it is proposed to work at the motor must then be assumed, and in this case let it be taken at 300 volts.

Dividing the total watts, viz., $\frac{21,950}{300} = 73{\cdot}16$ amperes required to feed the motor.

On reference to the table of conductors it will be found that a suitable cable, assuming a current density of 1,000 ampères per square inch, would be one composed of seven wires No. 11 L.S.G. with a resistance of ·5776 ohm per statute mile, the length of the cable being half a mile, *i.e.*, to the motor and back, it therefore follows that the resistance of these mains would be ·2888 ohm.

Taking the formula already given for finding the loss in watts in a cable, *i.e.*, multiplying the current by itself, or squaring it and multiplying by the resistance of the cable, it will be found that :—

73·16 ampères × 73·16 ampères × ·2888 ohm resistance = 1,546 watts lost.

The watts lost must now be added to the watts consumed by the motor, as under, viz. :—

Watts consumed by motor	21,950
Watts lost in cables	1,546
Total	23,496

Therefore the generating dynamo must be capable of giving an output in watts equal to the above.

As the current was 73·16 ampères, all that is therefore necessary is to divide the watts required at the dynamo by the ampères, which gives the voltage at the dynamo terminals, say,

$$\text{Total watts } \frac{23{,}496}{73{\cdot}16} = 322 \text{ volts at dynamo terminals.}$$

From the above it will be noted that the loss in the cables equals, say, 7 per cent. of the electrical output of the dynamo.

To find the total percentage of efficiency, *i.e.*, between the effective horse-power on the dynamo spindle and the effective horse-power given off at the motor spindle, the formula becomes, assuming an efficiency at the dynamo of 85 per cent., as under:—

$$\frac{\text{Total watts of dynamo} = 23{,}496 \times 100}{746 \times 85} = 37 \text{ effective horse-power}$$

required to drive the dynamo.

Assuming the efficiency of the engine driving the dynamo is 85 per cent., *i.e.*, the difference between the indicated and the effective horse-power, the indicated horse-power of the engine will therefore be:—

Effective horse-power required on dynamo spindle

$$\frac{37 \times 100}{85} = 43{\cdot}5$$

indicated horse-power to drive the dynamos. Therefore the efficiency between the indicated horse-power of the engine and the horse-power given off at the motor spindle will be

$$\frac{25 \times 100}{43{\cdot}5} = 57{\cdot}4 \text{ per cent.}$$

The writer trusts he will be pardoned for going so fully into tl formula, but it is the formula by which the efficiency of any transmiss of power plant is governed, and as it will be necessary to apply it to scheme which may have to be carried out, he thinks it will be of valu

The drawing on Plate XVII. represents the system described al and on this drawing the sizes of cable are given for reference.

Diagram, Plate XVIII., represents a transmission of power in tion and shows the method adopted where electric motors are fitte each shop.

On reference to the diagram it will be noted that a horizonta' engine marked S E drives on to the dynamo D. The current f dynamo is taken to a distributing switchboard marked D S B, a this point five branch positive mains are led to five motors place pattern shop, foundry, machine shop, heavy machine shop, and shop, the negative mains being coupled together and returni distributing bar on the distributing switchboard.

This diagram fairly represents the arrangement that would be adopted in a works where it is intended to drive each shop with a separate motor, and may be useful as indicating the general lines upon which a plant of this description should be laid down and the method of running the cables to the motors.

It would be an advantage in a system of this kind to have a separate ampère-meter to each circuit so that the current flowing to any motor can be seen at a glance. This would be a further indication that the motors were working satisfactorily, and in the event of any particular motor taking more current than it should do under normal conditions, the excess current could be instantly checked and waste prevented.

Diagram, Plate XIX., represents a transmission of power plant where separate motors are used for the large machines, and one motor for driving the line shafting for the small machines.

On reference to the diagram the steam engine is marked S E, the dynamo by D, and the main switchboard by M S B. From the main switchboard a pair of main cables are run round the shop and the various electric motors tapped off in parallel, contact being made simply from the positive and negative mains to the positive and negative terminals of the motors.

It will be noted from the diagram that the shop in question, which may be taken as representing an ordinary machine shop, consists of two planing machines, one large face plate lathe, one large shaping lathe, and one drilling machine, each of these machines being driven by a separate motor, and six small lathes driven by a motor which drives on to the line shaft, the lathe being fitted with the ordinary countershaft.

From the above diagrams it will be noted that the principles upon which ordinary transmission of power plants are laid out are very simple.

Having considered the loss in cables and in transmitting power from a steam engine of small size, but of a fairly efficient type, over a distance of 440 yards, it becomes necessary to consider, comparing this system with steam power, what the loss would be, assuming steam had been used.

Referring to the losses due to the condensation of steam in long pipes, attention may be drawn to some tests carried out by Mr. Hy. Davey, M. Inst. C.E., on a 7½ inches diameter steam pipe, 1 inch thick, and 1,100 feet long, conveying steam at a pressure of 45 lbs. per square inch to an underground pumping engine in the Morton Pit at Clay Cross, the pipes being covered with a non-conducting cement. As the result of careful observation it was found that the condensation of steam in the

pipe amounted to 500 lbs. per hour when the engine was standing, and 750 lbs. per hour when the engine was working, equivalent to ·183 and ·274 lb. per square foot of surface of pipe per hour respectively.

In another experiment carried out by Mr. W. Worby Beaumont, M. Inst. C.E., at the Staveley Hill Collieries, it was found that in a total length of 2,300 feet, 1,900 feet of which was underground, and covered in some instances to a depth of 2 feet, with rough stuff left after cutting away the coal, the condensation in a 6½ inches pipe, 1⅛ inches thick, conveying steam at an average pressure of 34 lbs. per square inch, was 600 lbs. per hour with the engine standing, and 1,400 lbs. per hour with the engine at work, equivalent respectively to a condensation of ·113 and ·265 lb. per square foot of surface of pipe per hour.

In dealing with the losses under the second head, viz., those due to the inefficient working of the engines at low loads, it will probably be sufficient for the present purpose to briefly consider the conditions under which such engines work. In most instances the engine has been originally put down of an ample size for the maximum power likely to be required from it, while the average power is in the majority of cases probably 25 to 50 per cent. of the maximum. Working under these conditions, especially with non-condensing engines, it is not surprising that the results obtained are very uneconomical. Perhaps the most striking instance of the wastefulness of this method of working is to be found in the following tests, carried out on some small workshop engines at Birmingham :—

Nominal Horse-power.	Probable I.H.P. at Full Load.	Average Actual I.H.P. per Hour during Test.	Coal Consumption in Lbs. per I.H.P. per Hour during Test.
4·	—	2·96	36
15·	45·	7·37	21·25
20·	60·	8·20	22·61
15·	45·	8·60	18·13
25·	75·	23 64	11·86
20·	60·	19·08	9·53
20·	60·	20·	8·50

These figures are interesting, as they actually represent the loss in steam pipes which have been well covered, and upon engines of a size generally found in workshops.

In our President's very valuable address, which has, to a great extent, completely cut the ground from under the writer's feet, he has brought forward some most valuable information respecting the consumption of steam in engines in his own works, and on reference to his figures it will

be seen that they correspond very nearly with the efficiency of the small engines which the writer gives above.

The writer has further prepared an estimate of the approximate cost of:—1st. A complete steam power plant, consisting of boilers, steam pipes, and ten horizontal engines each of 25 effective horse-power. 2nd. An electric plant, consisting of a high-class compound steam engine, with boiler, dynamo, conducting cables, and ten 25 horse-power electric motors:—

No. 1—Steam Power Plant.

	£
Four boilers, 30 feet long by 7 feet diameter, complete with fitttings and mountings	1,400
Foundations for four boilers	500
Ten horizontal steam engines, each of 35 indicated horse-power, or say 25 efficient horse-power, each £160	1,600
Main steam pipes connecting the four boilers, together with branch steam pipes for the ten engines, at £60 each	600
Erecting four boilers, ten engines, and ten lengths of piping ...	500
Foundations for ten engines, at £20 each	200
Total	£4,800

No. 2—Electric Plant.

	£
Two Lancashire boilers, each 30 feet long by 7 feet diameter, for a working pressure of 120 lbs. per square inch, complete with fittings and mountings	700
One compound horizontal condensing steam engine of 400 indicated horse-power	950
Foundations for engine, boilers, dynamos, etc., exclusive of chimney	300
One dynamo, output say 225 units	1,000
Driving ropes	50
Main switchboard, with measuring instruments	100
Ten electric motors, each of 25 effective horse-power, at £140 ...	1,400
Cables for ten electric motors, say £20 each	200
Foundations for ten motors, say £5 each	50
Erection of plant, say	250
Total	£5,000

From the above it will be seen that the first cost of the steam plant may be slightly less than the electrical plant; but it will be necessary now to turn to the cost of working, and two approximate estimates are given—No. 1, of the approximate cost per annum of 3,000 hours for maintaining the steam plant; No. 2, the approximate cost per annum for maintaining the electrical plant for the same number of hours.

This calculation is based on the assumption that the ten small engines will each consume 40 lbs. of steam per indicated horse-power per hour,

or say 56 lbs. per effective horse-power, and to this an allowance of 20 per cent. has to be added for condensation in steam pipes, making the total consumption of steam equal to 68 lbs.

The evaporative efficiency of the boiler is taken at 6 lbs. of water per lb. of coal, which the writer considers a very ample allowance for the class of coal which is used in most engine works. Therefore the consumption of coal per effective horse-power will be, say, 11 lbs. per hour.

In the electrical plant the coal consumption is based on the assumption that the engines will require 15 lbs. of steam per indicated horse-power per hour, and the indicated horse-power of the engine is taken at 400. The evaporative efficiency of the boiler is taken at 6 lbs. of water per lb. of coal, which will be, say, 2½ lbs. of coal per indicated horse-power per hour.

STEAM PLANT.

	£	s.
Coal consumption for ten engines, each giving 25 effective horse-power, or say 350 indicated horse-power, *i.e.*, collectively 350 horse-power at 68 lbs. of steam per effective horse-power, including condensation in steam pipes at 11 lbs. of coal per effective horse-power per 3,000 hours working per annum = 3,683 tons at 6s. per ton	1,104	14
Labour—3 stokers and 4 men to look after the four engines; total, 7 men at 30s. per week, £10 10s. per week for 52 weeks ...	546	0
Water for boilers—7,140,000 gallons at 6d. per 1,000 gallons ...	178	10
Oil for ten engines at 7s. 6d. per week	195	0
5 per cent. interest on capital outlay, £4,800	240	0
5 per cent. depreciation on capital outlay, £4,800	240	0
The total cost therefore comes to	£2,504	14

ELECTRICAL PLANT.

	£	s.
Coal consumption for 400 indicated horse-power at 15 lbs. of steam per indicated horse-power per hour for 3,000 hours at 2½ lbs. of coal per indicated horse-power per hour = 1,334 tons at 6s. per ton	400	4
Labour—1 stoker, 1 engineman, and 1 man to attend to electric motors at 30s. per week, £4 10s. per week for 52 weeks ...	234	0
Water for 1,800,000 gallons at 6d. per 1,000 gallons	45	0
Oil for engine and ten motors at 30s. per week	78	0
5 per cent. interest on capital outlay, £5,000	250	0
5 per cent. depreciation on capital outlay, £5,000	250	0
The total cost is therefore	£1,257	0

From the above it will be noted that the actual saving in favour of the electrical plant will be £1,247 4s. per annum, so that the total cost of the plant would be saved in, say, four years compared with a steam plant, which would cost practically as much money to erect. The above

figures show that an effective horse-power by a steam plant can be obtained for £10 per annum. An effective horse-power by electricity can be obtained for £5 per annum.

The writer trusts that the above estimates, which are of course more or less approximate, will be criticised by the members present.

A practical example of the efficiency and saving of an electrical plant over a steam plant is obtained from the writer's own experience in his firm's works in Newcastle. Prior to the adoption of electric motors the works were driven by a Cornish boiler 25 feet long by 6 feet diameter, 60 lbs. working pressure, a semi-portable engine of 50 effective horse-power, and a vertical boiler of 20 horse-power. The Cornish and vertical boilers steamed the engine in the machine shop, and also supplied steam to the engine in the erecting shop for testing dynamos, the semi-portable engine being used for driving the erecting shop and pattern shop.

As this plant occupied very valuable space, the writer's works being in Newcastle, where rents are very high, it was decided to take it out, and to put down a plant consisting of two locomotive boilers of 160 horse-power collectively, 160 lbs. working pressure; one vertical compound steam engine, with cylinders 9 by 18 by 10 inches, giving approximately 100 indicated horse-power; and one dynamo, to give an output of about 40,000 watts.

This plant now drives electric motors in the pattern shop, erecting shop, foundry, and a number of small motors in the tool shop, etc., with the result that by the removal of the old steam plant from the centre of the works a new shop has been erected, 90 feet long by 45 feet wide, two men have been dispensed with for attending to the engines and boilers, and the coal consumption has been reduced from 25 tons per week to about 12 tons per week, and it cannot be estimated that the annual saving is less than £700.

Class of Motor.

In laying down an electric transmission plant it is necessary to consider the class of motor most suited for the particular work that it is required to drive.

Plate XX.—Figure 1 represents the winding of the magnets of a series-wound motor; Figure 2 represents the windings of a shunt-wound motor; and Figure 3 represents the windings of a compound motor.

The series-wound motor is used in positions where great starting power is required, such as for cranes, haulage gears in collieries, and for single motors for driving pumps and heavy machinery, where the load is

constant after being once applied. This motor, however, does not give a constant speed, and is therefore unsuited for machinery where the load is variable and the speed required to be constant; a shunt-wound motor has not the same starting power, but possesses the advantage of running at a practically constant speed under any conditions of load, and is therefore particularly suitable for driving light machinery where it is necessary to maintain an absolutely constant speed under varying loads.

A compound-wound motor (which is a machine very seldom made) is a combination of a series and a shunt machine, and whilst it has not the perfect regulation of speed that can be obtained from a shunt motor, it has the advantage that by the addition of a series coil considerable starting power can be obtained. This type of motor the writer has fitted on to cranes, where the motor is allowed to run constantly, with great success.

Reduction Gear.

As a motor generally runs at a speed considerably in excess of the speed of the machine which it is intended to drive it is necessary to reduce this by one or other of the following methods:—1. Worm gear. The writer has supplied worm gear to electrical power plants with very great success, but if this gear has to run properly it must be very accurately made, and it is desirable that the worm should be at least double, and, if possible, treble threaded. A satisfactory material for the worm and worm wheel, is case-hardened wrought iron for the worm, and phosphor-bronze for the worm wheel. 2. A very ingenious, and at the same time compact and economical, type of reduction gear is the Humpage and Jacques, as shown. This gear, it will be noted, consists of bevel wheels placed in a box. The box can be filled with oil or other lubricating material, and the whole gear occupies very little space.

A third method is a reduction entirely by spur gearing. This method of driving is usually very objectionable, because it is almost impossible to prevent considerable jar upon the wheels owing to their high speed, with the result that it is not an unusual thing to see the wheels strip, also vibration is set up in the armature of the motor, which is almost certain to cause damage sooner or later.

A fourth system is a combination of belt driving and spur driving, the belt being placed between the motor and the countershaft of the machine. The belt acts as an elastic medium between the motor and the gear, it takes all vibration off the motor, and works extremely satisfactory.

A fifth system is entirely by belts, and probably for general work, particularly in engine works, this type of gear will find most favour.

It is, however, absolutely necessary to consider in laying down any works where motors are to be used, particularly in the case of individual machines, that a more or less considerable loss exists in the reduction gear necessary between the motor and the machine, and it is not safe as a general practice to allow less than, say, 15 to 25 per cent. for this loss.

The writer trusts that the remarks he has made, together with the comparative estimates and general information in the paper, will be of value to the members, and regrets having taken so much time.

Some lantern slides, showing the application of the electrical driving to colliery machinery, etc., were shown, amongst which were the following, illustrations of which are given herewith.

DESCRIPTION OF MACHINES, ETC., SHOWN THROUGH THE LANTERN.

Plate XXI.—Standard pattern of Tyne dynamo specially constructed for lighting and transmission of power work. The same type of machine is used as a motor, and is made in all sizes from 1 to 100 effective horse-power.

Plate XXII.—Portable electric drilling machine, made in three sizes, to drill from ½ to 1½ inch holes. The motor is of the enclosed type, and is fitted with a slipping coupling, together with a flexible shaft and drill head, as illustrated.

Plate XXIII.—40 horse-power Tyne electric motor and fan combined. The fan illustrated is capable of discharging 30,000 cubic feet of air per minute, at a pressure of 5 inches, when running at a speed of 600 revolutions per minute. These motors can be made in all sizes.

Plate XXIV.—Electric coal-cutting machine with swinging bar. The illustration represents the machine with the cover removed to show the working parts.

Plate XXV.—Three-throw electric pumping machines supplied to the North Seaton Colliery. The pumps are fitted with rams 9 inches diameter by 15 inches stroke, and are capable of delivering up to 300 gallons of water per minute. These pumps are placed 1¼ miles away from the dynamo, which is at bank, driven by a vertical steam engine. This plant has been running for over two years without costing a single penny for repairs.

Plate XXVI.—Portable electric pumping plant supplied to the Newton Coal Company, Newton Colliery, Felton. This plant is fitted with two rams, 6 inches diameter by 10 inches stroke, and will deliver up to 100 gallons of water per minute. This plant is also specially constructed for dip pumping, and is made in all sizes.

Plate XXVII.—Electric pumping plant supplied to the Shilbottle Company, for the Shilbottle Colliery. The pumps are of the three-throw type, having rams 7 inches diameter by 12 inches stroke, and are constructed to deliver 200 gallons of water per minute against a head of 200 feet. Special attention is called to the design of the bedplate, it being made in portions so that it can be easily got down the pit.

Plate XXVIII.—Small electric pumping plant, made in three sizes, to deliver up to 300 gallons of water per hour. This plant was supplied to a private mansion, and is placed at the side of the river, the switch being in the kitchen, can be turned on or off by the servants as required. The delivery pipes are taken up to the house, and the tank is placed in the kitchen.

Plate XXIX.—Electric capstan. Two capstans of this size were supplied to the Co-operative Wholesale Society, for their Dunston Flour Mills at Dunston-on-Tyne, and are used for drawing truck loads of coal and coke along the jetty. The motors combined with these capstans are of effective horse-power, and they have worked for over two years mo satisfactorily.

Plate XXX.—Set of three-throw ram pumps, with rams 9 inch diameter by 15 inches stroke, to deliver 300 gallons of water per minu against a head of 500 feet, driven by an electric motor of 55 effecti horse-power. Supplied to Messrs. Strakers & Love.

Plate XXXI.—Set of three-throw ram pumps supplied to the Colt Iron Company, Newmains; these pumps were fitted with rams 6 inch diameter by 9 inches stroke, and deliver 125 gallons per minute agains head of 150 feet. The pumps are driven by an electric motor of effective horse-power. This photo may be taken as representative of t type of three-throw pumps supplied by Messrs. Scott & Mountain for ordinary work, up to heads of 250 feet, and show the interchange system of pump by the valve boxes and delivery and suction pipes.

Plate XXXII.—Represents six sets of motors, with worm gear crank shafts, supplied to the Cowpen Coal Company for their Ca Colliery, to dispense with wire rope pumping. In all, eight sets as shown, have been supplied, *i.e.*, dynamo of 50 units output p bank and driven by a Corliss engine, and the gears occupy the sa tion as the old wire rope pulleys, the latter having been take the gears substituted. The connecting rod of the existing coupled to the crank pin of the gear, as shown.

Plate XXXIII.—Single gear, which more clearly shows t tion. In practice the worm wheels were covered over by a sh

but they are shown uncovered to more clearly explain the construction of the machine; the worm gears are specially made to avoid friction, the worms being case-hardened of wrought iron, and the worm wheels of phosphor-bronze with teeth accurately machined.

Plate XXXIV.—This represents the actual attachment of the electrical motor, and worm gear to the existing colliery pump; the pumps to which these gears were attached were 8 inches diameter by 15 inches stroke, double-acting.

Plate XXXV.—Tyne compound-wound dynamo of Scott & Mountain's War Office type, constructed to run 1,000 16 c.p. incandescent lamps at a speed of 550 revolutions per minute. Similar dynamos to the above are in hand for the Ashington Coal Company and Messrs. Bainbridge & Co.

Plate XXXVI.—Tyne alternating current dynamo; the armature is of the disc pattern, the field magnets being placed vertically round the armature, as shown, with collecting rings at each end. This type of dynamo is largely used for central station lighting.

Plate XXXVII.—Tyne dynamo, constructed for driving with gas engines. It will be noted that the dynamo is fitted with a cast iron bed-plate, with a very heavy turned fly wheel, absolutely steadying the light.

Plate XXXVIII.—Single cylinder vertical engine, with cast iron back standard, and turned steel columns in front. This engine is largely made by us for driving electric light installations and pumping plants, the engines being made with cylinders 5 inches diameter by 4 inches stroke to 13½ inches diameter by 10 inches stroke.

Plate XXXIX.—Compound vertical steam engine of the same type. The speed of the engine is controlled by a crank shaft governor, and it will be noted that the engine is fitted with continuous oiling gear throughout. Both the previous types of engines may be coupled to dynamos direct, when required. See following plate.

Plate XL.—Vertical single cylinder steam engine coupled direct to a Tyne compound wound dynamo. This plant is very suitable for placing in cramped positions, and occupies very little space, it is also very suitable for ship lighting, for which purpose a large number of plants have been supplied.

Plate XLI.—Compound vertical engine coupled direct to an Admiralty type dynamo. This plant represents, fairly accurately, the type of engine and dynamo used by the navy for warships. The plant in question was constructed to run 600·16 c.p. incandescent lamps with a working pressure of 90 lbs. per square inch, the engines having cylinders 10 by 16 by 40 inches, and the dynamo giving 50,000 watts at a speed of 350 revolutions per minute.

Plate XLII.—Small Scott & Mountain electric motor. These motors are made from ½ to 1 horse-power driving a small fan by belt. This type of motor has been supplied by us for driving lamp cleaning machinery in lamp cabins, and also for driving lathes and other small machinery in isolated positions, where it is not desirous to take shafting.

Plate XLIII.—Electrical organ-blowing gear supplied to Dr. W. T. Paget Tomlinson. Electric motor to blow the bellows of a large chamber organ, the motor being worked from the electric light mains of the mansion. The motor is of the Tyne type mounted upon a bedplate extended at one end to carry worm wheel brackets and a worm shaft, the motor being coupled direct to the worm shaft.

Plate XLIV.—25 horse-power Tyne electric motor and fan combined. The fan illustrated is capable of discharging 19,000 cubic feet of air at a pressure of 5 inches when running at a speed of 900 revolutions per minute. The type of motor shown is specially arranged to work vertically, and is intended for use for ventilating forced draught, etc. Two of these fans have already been adopted for induced draught for boilers, similar to the 40 horse-power motor and fan combined. (See Plate XXIII.)

The discussion was deferred, and the meeting dissolved.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

ELEVENTH SESSION, 1894–95.

PROCEEDINGS.

FIFTH GENERAL MEETING OF THE SESSION, HELD IN THE LECTURE HALL OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-UPON-TYNE, ON TUESDAY EVENING, FEBRUARY 12TH, 1895.

JOHN GRAVELL, ESQ., VICE-PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, held in Newcastle-upon-Tyne, on January 15th, 1895, which were approved by the members present, and signed by the Chairman.

The ballot for new members having been taken, the Chairman appointed Messrs. William C. Mountain and H. Foster to examine the voting papers, and the following gentlemen were declared elected:—

MEMBER.

Holgate, Charles H., Engineering Representative of Messrs. Whitley Partners, Leeds; Cardigan Villa, Grove Lane, Headingly, Leeds.

ASSOCIATES.

Mail, Douglas B., Marine Superintendent, 14, Humbleton View, Sunderland.
Sinclair, John, Shipowner, Church Street, West Hartlepool.

GRADUATE.

Olsen, Hans B., Jun., Apprentice Engineer, Wellington Road, West Hartlepool.

Mr. F. CAWS replied to the discussion on his paper on "An Account of some Experimental Studies of Ship Acceleration and Fluid Resistance."

The discussion on Mr. W. C. Mountain's paper on "The Design and Efficiency of Plant for the Transmission of Power by Electricity" was opened and adjourned.

Mr. HENRY FOSTER read a paper "On the Application of the Electric Arc to Machinery and Boiler Repairs, etc."

MR. F. CAWS'S REPLY TO THE DISCUSSION ON HIS PAPER ON "AN ACCOUNT OF SOME EXPERIMENTAL STUDIES OF SHIP ACCELERATION AND FLUID RESISTANCE."

Mr. F. Caws, replying to the discussion on his paper, said Mr. J. Denholm Young had fully realised the consequences of the principles, if true, embodied in this account of experiments at Wallsend; and he very properly exhibited these consequences in the extreme illustration of a ship getting up speed broadside-on and bow-on. But Mr. Young was not the first to point out this apparently absurd consequence. It was first pointed out to the author ten years ago; and, in order to learn the truth upon this curious question, experiments were made in towing a ship model broadside-on, which was rather a difficult thing to do. It was then found that the model in this manner attained her full speed, a ridiculously slow one, by means of a towing weight which was able to raise the same ship bow-on to a tremendously high speed. But that slow speed, which was the maximum when broadside-on, was arrived at in a much shorter time than the high speed, which was the maximum when bow-on; the same towing weight being employed in both instances. That was to say, it was thus found that the duration of the accelerative process was greatly reduced by making the ship go broadside-on, but the acceleration itself remained the same as for bow-on with the same towing weight. That was how Nature escaped Mr. Young's dilemma.

To show this more plainly, let them take, for example, a ship of full size whose acceleration was, say, $\frac{1}{20}$ foot per second, when driven by a constant power capable of raising her bow-on to, say, a full speed of 20 feet per second, or broadside-on to, say, a full speed of $\frac{1}{2}$ foot per second. The time of attaining the full speed bow-on was in that case 400 seconds, but the full speed broadside-on would be got in 10 seconds. What was there in this simple statement of fact to "startle" any one? The fact was only what their common-sense itself would have led them to expect if they had really taken the trouble to think the matter out in an unprejudiced way. For the thrust was the accelerative force and was constant and equal in both the bow-on and broadside-on runs of the same ship of the same displacement. How, in the name of common-sense, could acceleration differ or vary while the accelerative force remained

equal and constant? That was the question with which those w disbelieved the plain facts and principles of the Wallsend experimer were confronted, and which they were bound to answer, or else aband their unbelief in testimony of those experiments.

Mr. Young said this testimony, as given in the paper, "implied th the difference in the amount of the mass of water that has to be set motion by a full ship and a fine ship respectively does not affect t performance until the fuller vessel has reached her full speed." In ord that this objection might be presented, in fairness to Mr. Young, in t clearest and most forcible way, it might be illustrated thus:—The sh broadside-on at her maximum speed of ½ foot per second raises a gre wave, but, driven by the same power bow-on, at the end of the ten second from starting she will be momentarily going at ½ foot per seco velocity, on her way to her full speed of 20 feet per second. And wh at the velocity of ½ foot per second she will have raised an apparent very little wave. Now, Mr. Young regarded this great wave of t broadside-on motion as a great mass expressing a great resistance; a the little wave of the bow-on motion at the end of that tenth second fro the start as a little mass expressing a little resistance; and, thinki thus only of the difference in the sizes of the apparent waves, naturally failed to see how the same towing weight, when pulli against a great wave mass, could have the same acceleration as wh pulling against a little wave mass. He had lost sight of the fact th in the former case the towing weight had nothing else to do but to p against the great wave mass, but in the latter case, in addition to energy it was expending on the apparently little wave mass, the tow weight was expending energy in accelerating the ship. And when t added the energy expressed by the little wave to the energy expressed the acceleration of the ship's motion, they found that the total expendi was going on at the same rate in the bow-on motion as in the broadside motion, for not only was the towing mass equal in both cases, but t masses towed were likewise equal in both cases; hence the accelerati was equal in both cases, and hence also the resistance was equal in bo cases. That was to say the bow-on resistance of the 20 feet per seco speed and the broadside-on resistance of the ½ foot per second speed we equal; and the wave masses in these two cases were likewise equal, *i.* equal to one another not only at the full speed, but also (in the potenti plus kinetic equal constant sense) during the gaining of that speed the equal and constant towing weight or power. When Mr. Young spo of "the difference in the amount of the mass of water that *has to be* s

in motion" by the broadside-on and bow-on ship respectively, he spoke potentially as well as kinetically, but spoke of what did not exist, for in point of fact there was, except in a merely kinetic, and therefore partial, sense, absolutely no difference at all. The great wave of the broadside-on, ½ foot per second full speed ten seconds from the start, and the little wave of the bow-on ½ foot per second accelerating speed ten seconds from the start, although so apparently different in mass, were really of equal mass. The difference between these two waves was not a difference of "amount" of mass but of period and phase of mass. Thus, ten seconds from the start the whole mass of the great wave was in momentum, and was visibly developed in the full speed disturbance of the vessel moving broadside-on. But the whole (and equally great) mass of the escapement wave of the bow-on motion at the ½ foot per second accelerating speed, ten seconds from the start, was mostly in its inertial phase, not visibly developed, but in the acceleration of the ship herself giving promise of development; that which they had called the small wave being simply the small portion of wave mass whose inertia had already, in the ten seconds of motion, become converted to momentum. If they would understand wave masses and motions they must apply to their phenomena the $p + k = C$ principle of interpretation. By this principle law and order became plainly apparent. Without this principle they plunged at every turn into misconception, chaos, and confusion.

The following symbols might serve to illustrate the application of the $p + k = C$ principle to ship's acceleration, resistance, and waves. [It must not be forgotten that skin resistance had the effect of swelling the wave of escapement. Therefore the measure of the wave's inertia includes, in the measure of its own mass, the effect of the skin resistance.]

D = ship's displacement mass.

W = towing or propelling mass.

I = inertia of D which W could convert to momentum.

I = escapement wave mass, otherwise known as R = resistance.

W = I = R, not only at full speed, but likewise at every moment of acceleration.

The momentum derived from the energy of W, which was expended wholly in overcoming or converting I, was *lost*, because it was entirely devoted to giving motion to waters which the ship left behind, and whose motion contributed to the ship's motion no help. Hence the measure of momentum of the escapement wave was the measure of loss of energy paid by W as the price or penalty for the ship's motion, which was what was commonly called resistance.

In accordance with these views the above symbols might be supplemented thus:—i_1, i_2, i_3, i_4, etc. = that portion of I which had been converted into momentum of wave at the respective moments 1, 2, 3, 4, etc. $I - i$ = the remaining portion of I which at any moment continued to resist conversion into momentum, from which it was seen that, as $I - i + i = I = W$, the inertial resistance of wave plus the accelerative force lost on wave momentum, were, in the $p + k = C$ sense, equal and constant throughout the whole motion whether accelerating or at full speed.

Mr. Young, wisely, with the characteristic caution of the scientist had refrained from denying the conclusions of the paper. He seemed conscious that they could not well be denied if the facts therein stated were facts indeed. He therefore proceeded to argue that, owing to the enormous disproportion between a small scale model and the full-size ship, errors of comparison must accrue; and, of course, his inference was that in the Wallsend experiments such errors might or must have been large enough to heavily discount, if not to quite discredit, the results.

If they were to carry Mr. Young's arguments on this point to their full conclusion, they should not in ordinary business life use small scale drawings and models for ships and engineering works of great magnitude in the way they did and must. The liability to error was great. But in spite of that, by skill and care, they were able to obtain help and guidance of very great value from these small scale drawings and models and likewise they were able to do so from model trials of speed and resistance. Mr. Young himself last year, with reference to the speed power results up to that time obtained by the pendulum meter at Sunderland, remarked in his address to the Institution, that, notwithstanding his reasons for withholding assent from the theory of that meter he felt struck by the fact that the results obtained from it compared remarkably with the real ship's actual speed-power curves. And it was certain that if Mr. Young had before him now the results since obtained in the same tank, in the cases of more than fifty curves supplied to local shipbuilders as a basis of practical estimates and guarantees, he would be more than ever favourably impressed with the great accuracy of the instrument, which could in truth be relied on to repeat its performance to the $\frac{1}{100}$ inch of ship model's travel.

But, putting these considerations and actual experiences out of view for argument's sake, let it be admitted that scale errors were even much greater than Mr. Young suggested, let it be allowed that they were so great as to deprive small scale drawings, and small scale models, and

model trials, not of a part only, but of all their reliability as a means of estimating the cargo carrying capacity, cost, weight, or speed and resistance of any full-sized ship. Did that admission in any degree discount the testimony of those Wallsend experiments which, and which alone, were the proper subject of this present discussion? If a model 5 feet long could not be relied on to indicate shape, displacement, trim, stability, or speed and resistance of a ship 405 feet long, could not a model 5 feet long be relied on to yield, under similar experimental tests, results accurately comparable with those of another model, say, 12 feet long, and of a third and fourth model each, say, about 16 inches long? Mr. Young, in this part of his argument, had lost sight of the fact that the testimony of the Wallsend experiments now under review was not due in any degree to a comparison of model performance with that of full-sized ships, but was the testimony of various models of various sizes tested under various conditions one against the other, simply to discover their common principle of acceleration, so that Mr. Young's objections on the score of scale had really no bearing on the point now at issue. But Mr. Young might say, admitting that errors due to scale had no bearing on these experiments now under discussion, still there were errors of operation and of observation to take into account. True; but would such errors, in the case of hundreds of experiments, extending over months and years, all conspire to produce an absolutely regular result, or would they not rather introduce eccentricities and irregularities? What Mr. Young had to face in the Wallsend tank testimony was the fact that the results always showed that the ship's acceleration was uniform, as stated in the paper. Mr. Young correctly pointed out that a time difference which might be, he thought, assumed as due to resistance would be too small to trace experimentally, and that the result as regarded the question now under review might depend on that infinitesimal time measure. But the measurements of motion were made, as the paper describes, not in measure of time per travel, but in measure of travel per time. To measure a second, or a fraction of a second, of time accurately is one thing, to measure a descent of 16 feet, or even of 1 foot or 1 inch, was quite another and much easier thing, a small measure of time showing a large measure of travel. Thus when the relative weights of D and W, and of B and S, were arranged to suit the formula, which one would, unless more deeply instructed, expect it to suit, viz.,

$$\text{ship's acceleration} = \frac{W}{D + W}\, g,$$

the refusal of W and B to arrive on their brackets simultaneously was very obvious and quite unmistakable.

Mr. Hök's much more pronounced criticism added greatly to the interest of this discussion, and might be met by a familiar but apt illustration. Their esteemed friend Mr. Macoll was heard on one occasion at a meeting of this Institution to advocate, with his characteristic humour, the improvement of the Whitley mile "by planting *mile* posts every $\frac{1}{4}$ mile apart!" Although as a very active member of the committee of Council Mr. Macoll had not been able to carry his $\frac{1}{4}$ mile divisions into practical effect, they expected soon to see the lofty new posts erected; and they would all rejoice if, by a revival of good times, these new posts were soon brought into more frequent requisition than ever the old posts were. If the new measured mile trials continued to be run on the same good old plan as heretofore, they might sometimes have ships running the mile in, say, 200 seconds, and skilled observers each with his stop-watch marking time to fifths of seconds (*i.e.*, to $\frac{1}{1000}$ of the whole time) and never, or seldom, agreeing absolutely as to the exact time the run took; but always obtaining results accurate enough for practical purposes. But suppose that one day soon, by special invitation of their good friend Mr. Hök, they accompanied him on a steamer's trial trip of which he had charge. And suppose they found that by Mr. Hök's direction the posts had been shifted, and stood no longer 1 mile, but only 3 yards apart! And, further, suppose they observed, as the steamer rushing at full speed of about 15 or 16 knots was about to cross the line of the first pair of posts, that Mr. Hök pulled out from his vest pocket in lieu of a stop-watch a little pendulum beating time to $\frac{1}{2}$ seconds; and they saw him start the pendulum and count its beats, while somebody else called for him "Now—now!" so that, between the interval of the two "nows" (*i.e.*, when the steamer was shooting the 3 yards between the two posts), Mr. Hök might measure the time interval; and suppose that after a few such runs, at different full-speeds each time, he pocketed his pendulum with a grave and gratified smile, and ordered the ship to return to port. If, a few days later, he produced a beautiful speed curve of that ship's performances, and said it was based on data obtained as described, surely they should be tempted to think Mr. Hök was playing a practical joke upon them, or else that over much devotion to logarithmic lore had twisted their good friend off his mental balance. They might in that case try to reason with him, and prove that if the ship was going at a speed of 15·8 knots she would cross the space of 3 yards between the two posts in about one-third of a second.

Mr. Hök must not complain of this singular illustration of his argument, for, fantastic though it might seem, it fairly, without any

exaggeration, represented the value of the logarithmic curve of resisted motion which he had put forward, a curve which, however ingenious the theory of it, and by whomsoever invented or approved, had not any basis whatever of experimental fact. And in such matters they must learn to reverence the smallest *fact* more than even the greatest *name*.

A close examination of the experiments referred to in Mr. Hök's communication, a detailed account of which would be found in *The Principia*, would show that these experiments served very well to support that great principle which Newton sought by their means to establish, a principle now universally recognised, viz., that the resistances of fluids vary as their densities. Anyone hearing Mr. Hök's letter to Mr. Duckitt read for the first time would get the impression that these experiments were more complete and accurate, and every way more extensive and reliable, than those at the Wallsend tank. To be disabused of this false impression one had only to refer to the account so faithfully given by Newton himself. The largest of the two tanks used by Newton in these experiments contained only 8 cubic feet of water, and the smaller one contained only $5\frac{1}{3}$ cubic feet, as against 640 cubic feet in the Wallsend tank. The globes used were little balls of loaded wax, about as big as billiard balls. In the deeper tube or tank their greatest descent was only $15\frac{1}{3}$ feet, and only $9\frac{1}{2}$ feet in the smaller tank. In each experiment nearly the whole space of the descent was fallen through by the ball at its uniform maximum speed. The space of accelerating descent was only from about 2 to 5 inches, and was generally accomplished in about one-third second. It was utterly impossible to tell by observation exactly how long it took the balls to fall these few inches, for the timekeeper employed was nothing better than a pendulum beating half seconds. The balls fell in the dark of the water, and could not be watched in falling, for there was no glass side to the tall boxes or tanks. These boxes were so narrow that Newton told them the balls were sometimes heard bumping against the sides as they descended, and an allowance for the increased resistance, due to the water being canalised by the narrowness of the boxes, had to be made in every experiment. Attempts to repeat the experiments seldom succeeded, for in most cases there were serious differences in the results as to the whole time of falling, differences ranging generally from one to three seconds! seldom less, and sometimes much more! Occasionally the balls reached the bottom of tank too soon, because they were never released automatically, and sometimes the hand, in dropping them, involuntarily contributed some impulse. No automatic provision, electrical or otherwise, secured absolute simul-

1 per cent. of error) these small spaces and times the instrument's defining power in time would need to be as infinitesimally true as to mark automatically the actual time of the experiment with certainty to $\frac{1}{100}$ of a second. But the instrument with which the great Newton made these experiments was able only to define $\frac{1}{2}$ seconds, and even then with no automatic arrangement by which simultaneous measure of time and space could be guaranteed.

Surely, if Mr. Hök would reflect on these facts and considerations, he would come to see that in the experiments he quoted there was no ground for his belief that they were proofs of the theory of his curve. If he would take the trouble to test those experiments he would find that their time errors were much too large to afford either proof or disproof of this false theory, the falseness of which had been absolutely demonstrated by the almost perfectly accurate time and space measures of the Wallsend experiments. As to the Wallsend models never reaching or nearly reaching full speed, Mr. Hök had not sufficient warrant. The sketch diagram accompanying the paper was not drawn to scale, but gave a fair general representation of the tank and apparatus. Not only were experiments made with a model of about the relative size shown on the sketch, but also with other vessels and models much larger and much smaller.

The little brass instrument upon the table (shown) was a pendulum dynamometer which the author of the paper invented and used largely in the earlier days of his Wallsend experiments. It indicated by the motions of its pointers the precise moment when a ship model attained full speed, and also faithfully exhibited the most interesting potential-kinetic play of forces preceding as well as following the attainment of full speed. This instrument would show Mr. Hök the whole meaning and bearing of those towline phenomena to which he referred, and would show him that his imagination had not been quite correct in leading him to charge the Wallsend tank apparatus with defectiveness in this important particular. It would require a whole paper to deal with the subject of towline tension and towline play, as exhibited by this instrument and others equally interesting which were used at Wallsend. It had a great scope of science and suggestion in it.

The accelerative distance of a ship was governed both by the speed and acceleration. Given the speed, the ship's lines determined the acceleration; given the acceleration, the ship's lines determined the speed. When the acceleration and speed were both known the accelerative time and space could be at once found. When the accelerative space was

known, together with the ship's displacement and thrust, the speed could at once be found. If speed, space, and thrust were known, displacement could be found. If speed, space, and displacement were known, thrust could be found. The principle yielding these results was that of gravity applied in the same way as when ascertaining the time, space, and velocity of masses falling through fluids and in vacuo, all of which was expressed in the following simple formulæ:—

$$\frac{W}{D} g = \text{acceleration.}$$

$$V = \text{full speed} = T \frac{W}{D} g.$$

$$T = \text{whole time of accelerative run} = V \div \frac{W}{D} g.$$

$$S = \quad \text{,, travel} \quad \text{,,} \quad \text{,,} \quad = \frac{TV}{2}.$$

These were some of the things "between the lines" of the paper which Mr. Hök appeared not to have seen; and there were many more things, especially regarding the relation of the ship's static to her moving displacement, which could not be gone into now, but which might be cleared up on some future occasion.

Mr. Hök's observations were, for the most part, arguments from experiments with bodies falling through water to disprove the Wallsend experiments of bodies floating on the water. If, as Mr. Hök said, he thought the two kinds of experiments were not dynamically on all fours with each other, then Mr. Hök's argument, even if not otherwise shattered in every part by facts, must by his own showing have lost all its application on this last named score alone, for in this particular it was not permissible for Mr. Hök to blow both hot and cold. He could not both have his cake and eat it. In this matter Mr. Hök ignored the fact that the paper employed the falling spheres merely as an illustration within expressly stated conventional limits, such as would necessitate that the relative densities of air and water remain unchanged at each level of the descent. But this was a subject quite beyond the scope of the paper, and seeing that the paper carefully abstained from committing itself on the point, it was not exactly right for Mr. Hök to drag it in to the argument. Mr. Hök said Newton performed experiments on globes falling through quicksilver. Here again it seemed evident that Mr. Hök had not informed himself of the exact facts.

Mr. Hök (interrupting) explained he had written Mr. Duckitt correcting that.

Mr. CAWS said he regretted he was unaware of the correction. The globes were of glass filled, some with air and some with quicksilver, and fell through air from the top of St. Paul's, London. The results suffered from a defect in the trap-door releasing arrangement, so that neither times nor distances worked out quite truly, for even after allowing for the defect referred to, the spaces of descent were from 4 to 11 feet in error. These experiments, however, went to prove the law of fluid resistances being simply proportional to their densities, but were not accurate enough to prove or disprove that further law of constant resistance during acceleration, which in a $p + k = C$ sense the Wallsend experiments bore testimony to. When they realised the crudeness of the apparatuses employed by Newton in such experiments, their defects served only to increase their admiration for the mighty mind that could work such wonders as he did with such poor tools.

Mr. Andrew Young was to be thanked for pointing out the *lapsus plumæ* by which in the paper the word acceleration had been used in one place where the meaning of the author was accelerative force. But this etymological correction left the argument unanswered. Mr. Young, in his remarks, betrayed a clinging to academic tradition, accompanied by a want of proper appreciation of the weight of facts, which prevented him from giving fairplay to the undoubtedly acute powers of his own mind. All that he said against the $p + k = C$ theory had been said in effect by others either now or in last year's discussion, and had been fully replied to. Mr. Andrew Young seemed impressed with the conviction that the inventor of the pendulum meter was of all men the least able to properly interpret and use it. There was another gentleman who once thought as Mr. Andrew Young appeared to think on the subject of pendulum kinematics —indeed he expended a great deal of earnest thought on it—and his ideas ran exactly on the lines indicated by the expression $\frac{ds}{dt}$ for velocity and $\frac{d^2s}{dt^2}$ for acceleration. At last, after many a weary argument, he undertook to work out, from the experimental data supplied by the pendulum meter, the speed-power of a ship. The upshot was that he made the effective horse-power exceed the indicated. The best answer Mr. Andrew Young could get to the observations he made on this subject was the answer which a similar experience would give him. He was welcome to the data from the Sunderland tank upon the express understanding that his curve of results would be published at a meeting of this Institution, together with the indicated horse-power of the real ship and an effective horse-power curve supplied by the meter on the $p + k = C$ principle of interpretation.

In thus replying to his critics the author of the paper had tried to keep steadfastly to the one proposition with which the paper set out, viz., that a constant thrust involved a constant acceleration. That other, and apparently still more paradoxical proposition, with which the paper concluded, and which had naturally excited adverse comment, viz., that $\frac{W}{D} g =$ acceleration, must (as was intended when it was thus announced) await its exposition till another occasion. Meanwhile it would serve as a very good target for the wit and wisdom of engineers, shipbuilders, and others. In bringing to its close this long reply, the writer of the paper felt sincerely grateful for the patient hearing he had had, and for the most kind expressions towards him personally which his three excellent critics, and still more excellent friends, Messrs. Denholm Young, Hök, and Andrew Young, had embodied in their communication.

On the motion of the CHAIRMAN, a vote of thanks to Mr. Caws for his paper was adopted by acclamation.

DISCUSSION ON MR. W. C. MOUNTAIN'S PAPER ON "TRANSMISSION OF POWER BY ELECTRICITY."

Mr. Frank Broadbent, who opened the discussion on Mr. Mountain's paper, said that this being his first appearance before the North-East Coast Institution he hoped he would be granted the usual leniency accorded to such efforts. Of course when Mr. Mountain read a paper they expected something intensely practical and not theoretical only, and they had not been disappointed in the paper under review. He noted that Mr. Mountain went to elementary principles first of all, and seemed to think that they should be taught what units were, and how derived before proceeding to the actual substance of the paper itself. On the occasion of Mr. Mountain's last paper he thought there was not much necessity for that, but on speaking to several members of the Institution they said they quite appreciated that phase of the paper because they knew so little about electricity, and had so little time to study it, that such papers as these were their only means of getting information upon the subject—information put in a condensed form. That being so, he thought the author of this paper should have been very careful as to the language he used in speaking about the units. In the first place, Mr. Mountain told them that "the practical units which corresponded to the pressure and foot-pounds, as used by engineers, were the volt, the ampère, the ohm, and the watt." He quite agreed that, in speaking of "electric motive force" or pressure, electrical engineers used the expression in almost the same way as engineers spoke about "pressure to the square inch," but when they came to "foot-pounds," *i.e.*, work actually done, he did not see any analogy between the "ampère" and "watt," as these were rates of doing something, one being a rate of flow and the other the rate of doing work, *i.e.*, power. If he had said "foot-pounds per minute or per second," that would have meant power, and the ampère and watt would then practically have been a fair analogy. He thought it was Mr. James Swinburne who said that to give an analogy to a sensible audience was an insult to their intelligence. He (Mr. Broadbent) did not quite follow him to that extent; but he thought they should be careful in using any analogy, and especially in such a paper as this, where what was set down was taken as being absolutely correct. Then, passing on, they were told the volt equalled one hundred million C.G.S. units. He did not think that conveyed the slightest impression to the mind of

the mechanical engineer, for one might just as well try to explain what a pound or a foot was; they could only appreciate such things by actual experience with weights and measures. He did not think those analogies and descriptions were of any use at all. Then they were told that "a watt or volt-ampère was the amount of work done in a second by the dynamo," and only three lines below this a dynamo was mentioned as having an output of 10,000 watts. Clearly, then, a watt was only the unit by which the output was measured. They passed on to the efficiency, and that which Mr. Mountain gave them was an efficiency very seldom used. He did not know that he had ever heard it used before. The total electrical energy generated in a machine was immaterial to the contracting engineer; what he required to know was the actual power given out by the machine as compared with the power put into it. He (Mr. Broadbent) thought if they compared the actual energy delivered by the dynamo with the actual mechanical energy put into it they would get the commercial efficiency, and in this sense Mr. Mountain was quite right in saying the efficiency might approach 93 per cent. He knew of a case where in a test taken of a "Castle" dynamo by Prof. Kennedy, of London, almost 96 per cent. was actually obtained. Then Mr. Mountain took them on to the design of dynamos. He told them it was advisable that all bearings should be made adjustable. He differed from him about this, for although split bearings might be necessary in a reciprocating engine, they were not in a rotatory machine like the dynamo, and to show this he took the liberty of bringing down an armature and couple of bearings,* which were not adjustable for wear in the sense of being split longitudinally, but they were self-aligning, and also self-lubricatin by means of a ring running in an oil well, which carried oil up t the spindle. Messrs. Holmes & Co. had machines of this kind runni for ten years without any appreciable wearing of the bushes. He d not think Mr. Mountain mentioned brushes very much; but m brushes had a rotatory motion, and as the brush wore away it altered position on the commutator, tending to produce sparking. Here t had a parallel motion, and the brushes never moved their position the first setting. Then about the magnet coils: Mr. Mountain said i always advisable to place them above the armature, as it prevent getting upon them. Clearly, in such a case the fault would lie design of the oiling arrangements, and not in the position of the m If they looked at the advertisements in any electrical paper they see the bulk of the coils were at the bottom. He quite admitte

* This machine was placed on the table for exhibition.

ever, it was better to have the coils above the armature for many reasons besides oil getting upon the magnets. He thought they might compliment Mr. Mountain upon arriving at that design, which he would find much superior to the single bobbin type. They were told also that the coils ought to be always wound on independent bobbins. That was a matter of cost, convenience, and size of machine. Where the machine was very large it was an advantage. Then they found Mr. Mountain speaking about "weak lines of magnetism." Here, too, there was a little looseness in the use of terms. So far as they knew anything about lines of magnetic force, they did not know of one being stronger than another. Their calculations were all based upon the assumption that lines of force were equal in strength. "Weak magnetic field," meaning that the lines of force were "few and far between," would be more in accord with everyday usage. In the example given of a dynamo supplying current to one motor having a certain resistance, Mr. Mountain was not speaking of resistance in the same terms as he defined it in the first part of his paper. He told them they had a resistance equal to 10 ohms in the motor and conductors, through which 10 ampères flowed, due to an E.M.F. of 100 volts. If that were so, where was the useful power coming from? Clearly, the whole of the power was absorbed by the resistance, and none was available to drive the motor. If Mr. Mountain had told them that what he meant was only *an apparent* resistance due to the back electro-motive force of the motor, he would have made it clearer. Mr. Mountain also told them that this motor would give out about $\frac{3}{4}$ brake horse-power; but he had clearly told them that a dynamo giving 100 volts by 10 ampères would require about $1\frac{1}{2}$ indicated horse-power to drive it, so that they only got an efficiency of 50 per cent., and he did not tell them where the other 50 per cent. had gone to. He (Mr. Broadbent) thought that in a paper where the writer started on such elementary principles he might have told them where that 50 per cent. had gone. Passing on from that, the paragraph about putting in motors too small for the work could not be too strongly insisted upon. It was often difficult to say with any degree of approximation what power a machine required, and one might be asked to quote for a motor to develop about 10 horse-power, and find eventually that they wanted 15 or 20 horse-power, and so the motor was overloaded. The motor would not stop; it would simply struggle on, and perhaps eventually burn up. Where possible, he would suggest when they wanted to replace a steam engine by a motor that they got a temporary one to drive the machines and measure the horse-power taken,

which could be done very accurately by electrical means. When that was ascertained, there would be no difficulty in determining the exact size of motor required. Passing over to the table of resistances, he would come to the question of conductors. It was pointed out, "By suitably proportioning the size of the cable to the work to be done, it is possible to make the power consumed in the cables anything that may be desired, but it must be borne in mind that by unreasonably increasing the size of the cable, and thus reducing the loss, a point is soon reached by which the first cost of the cable will be so high that the saving will not be economical." There was a law, known as Kelvin's law, which was to this effect, that the most economical size of a conductor to use for any given work was such that the annual interest on capital outlay on the conductor was equal to the annual money value of the loss of power in the conductor. The first cost and subsequent expense were directly proportional to the area of the conductor, the loss of power varying inversely as the area. Simple as the statement of Kelvin's law might be, the actual determination of the most economical size of the conductor was not so simple. In fact it formed one of the most difficult and tedious calculations of the scheme. The question of the economical size of conductors was so intricate and involved so many considerations that one was afraid to venture upon it for fear of trespassing too far upon the patience of the members, but as it formed such a very important item in the design and efficiency of transmission plants he felt that the writer of the paper might have enlarged upon it. He appeared, however, to have considered distribution of power in a covered works more than transmission to any considerable distance. For example, Mr. Mountain recommended all cables being covered with an insulating material, and fixed the minimum insulation resistance of such covering at 300 megohms per mile for low voltages. Whilst this was a very proper recommendation for cables in the vicinity of inflammable materials, it did not apply, and would in fact be a needless waste of money, to wires carried overhead in the open air, or along the outside of buildings, or in suitably constructed trenches underground. There were many cases where the cables might be absolutely bare, or at most merely covered with a protective braiding to prevent corrosion due to fumes, smoke, etc. To take the example given of driving a 25 horse-power motor at a distance of a quarter of a mile from the dynamo. The cable given for this was a comparatively small one, and, according to the author's recommendation, it must have an insulation resistance of 600 megohms per mile, as the voltage employed was over 200. The cost of this small cable would be

considerably more than double the cost of a bare or lightly insulated cable of exactly the same size; in fact about £50 would be absolutely thrown away, that was assuming the cable to be in the open air. For indoor work the conditions were different, and insulated conductors were desirable. Nothing was said in the paper about the variation in voltage at the motor end of the line, due to the varying load on the motor, and the effect that this variation would have on the speed. On the contrary they were told that a "shunt motor would run at a practically constant speed under all conditions of load," a statement which was approximately correct only, if the loss in the cables was insignificant and the voltage at the motor terminals constant. Just as the voltage at the terminals of a dynamo varied with the speed, so the speed of a motor varied with the voltage at its terminals; and as the volts lost in the conducting cables varied with the current flowing, and the current varied with the load on the motor, it was clear that as the load was altered the speed would also vary. It was necessary, therefore, in transmission work to have a means of adjusting the speed of the motor, and this was usually done by means of variable resistances. In the example given the volts at the motor terminals would vary from about 300 to 320 volts between no load and full load, producing a corresponding variation in the speed. It was possible, however, in a case of that kind, when there was only one circuit taken from the dynamo, to design the latter to give more volts at full load than at no load, and so compensate for the loss in the cables, and maintain a constant voltage at the distant end, notwithstanding varying load on the motor. Coming now to the estimated cost of a steam power plant as compared with an electric plant, it appeared to him that the same conditions of working had not been assumed in both cases. In the steam plant 68 lbs. of steam were allowed per effective horse-power per hour, or slightly over 11 lbs. of coal, which, according to the table of tests given, indicated that the average load was considerably less than half the maximum, whereas in the electric plant 2½ lbs. of coal only were allowed per indicated horse-power per hour, or 15 lbs. of steam, which was allowing a very high efficiency, even for full load, and was assuming no loss whatever by condensation in the pipes or cylinders. This appeared to give every possible advantage to the electrical system and none whatever to the steam plant. On the other hand, it might be pointed out, that for an ordinary works the electric generating plant proposed was larger than necessary. The engine was capable of indicating 400 horse-power, which was sufficient to drive simultaneously the whole of the ten motors at full load, with a total efficiency of 62½ per cent. $\left(\frac{250}{400} = \frac{\text{B.H.P.}}{\text{I.H.P.}}\right)$. It had

been shown, however, by other writers that about 70 per cent. of the aggregate power of the motors was the greatest load that need be provided for, except for very short periods. In Messrs. Siemens Bros'. works the motors in use were capable of giving an output of 1,407½ brake horse-power, whilst the generating plant was capable of developing only 1,200 indicated horse-power. If they took the same proportions in the example given by Mr. Mountain the indicated horse-power of the engine need only be about 212 instead of 400, the dynamo and boilers could be reduced in the same proportion, thus bringing the cost of the whole plant to probably £1,500 less than the steam plant. Even now the generating plant would run on the average at about three-quarter load. The question of accumulators had not been mentioned. It was sometimes worth considering whether or not it would be a saving to put in a generating plant sufficient for an average load, with sufficient storage capacity in accumulators to cope with the temporary heavy loads. This was all a question of the relation between the average day load and the maximum load, and in an ordinary works it would generally be cheaper to have the margin in the generating plant rather than put in accumulators, besides involving less attention. Upon the question of average day load as compared with the maximum output of the motors, Mr. Mountain might now give them some useful information from records taken of the plant in his firm's works. It would be interesting also to know how the annual saving of £700 was arrived at. The coal consumption was given as 12 tons per week, or 600 tons per year, allowing two weeks for holidays; whereas on the basis of the approximate cost of upkeep, given by Mr. Mountain, this should only be, say, 334 tons, assuming, as in the example given, that the plant was running at its full load of 100 indicated horse-power for 3,000 hours. That seemed a fair allowance, so that instead of 2½ lbs. per indicated horse-power, the actual consumption was more like 4½ lbs. Of course if the 12 tons per week included coal for foundry and for the machine shop engine, which, from Mr. Mountain's remarks at a previous meeting, was still driven by steam from the boilers, this allowance should be made; but even this would not account for almost half the total consumption. If Mr. Mountain had shown them more clearly what the saving was, it would have made his valuable and interesting paper, if possible, even more useful than it undoubtedly was.

Mr. H. F. PARSHALL (by permission of the Chairman) thanked the members for inviting him to take part in the discussion on Mr. Mountain's paper. He thought Mr. Mountain had succeeded very well in explaining

as a body of engineers not particularly interested in electrical matters the terms and general application of elementary formula used by electricians. If some of his analogies were not absolutely correct, looked at from a purely technical standpoint, he was of opinion they were sufficiently correct to serve the purpose intended. He might, perhaps, be permitted to congratulate Mr. Mountain upon his success in that direction. Electricians as a body had not generally succeeded in explaining to engineers the practical meaning of their terms and formulæ. Perhaps an extended criticism of his analogies would best be discussed before a body of engineers over which Lord Kelvin or a similar authority would be expected to preside. The efficiency of electrical motors had been spoken of several times. He should like to point out as of practical importance that a simple statement as to the efficiency of an electric motor at full load was not of great practical importance. What was wanted was a statement of the efficiency of the motor through the necessary gearing while performing its average work. As an illustration of this he would quote the case of a tram car motor. Tram car motors had been constructed with an efficiency at full load as high as 95 per cent. Such motors ran at so high a speed that after the speed had been sufficiently reduced by two sets of gearing, the result obtained at the car axle was less than with a motor of considerably lower efficiency that required but a single reduction, and in the case of light loads the motor of higher efficiency and higher speed was greatly inferior to the lower efficiency machine. Engineers who were familiar with the frequent trials made of steam engines knew that under practical working conditions the same efficiency as to steam consumption was rarely attained; in good practice the discrepancy amounted to 35 or 40 per cent. These engineers, no doubt, would wonder if the same state of affairs held with electric motors. He was in a position to say that it did not, provided that in the original statement as to efficiency the working conditions, such as loss in gearing and average load, were taken into consideration. There was no difficulty in doing this, as in the case of steam engines, where the quality of steam was of great importance. The question of adopting electricity to factories generally was being very widely considered. One of the principal advantages was the gain from substituting one or two large steam engines, working at the most economical load, in place of several smaller ones. The immediate gain from doing this was obvious, and, as shown by Mr. Mountain's figures, which he was in a position to state, had been realised in practice, and was worth the consideration of most manufacturers. Several installations had been carried out on the

Continent and in America, and in each case the results had been most gratifying. The economy in coal and attendance had been somewhat greater than was expected. In one particular case the engines that were scattered throughout the works were moved into one central station and the power transmitted by electricity. It was found that only half of the engines required to be run to develop the same power as formerly owing to the compensation among the different machine shops. Of the advantages of electric cranes, especially over the steam cranes so commonly in use, he need hardly speak. great number of electric cranes were now in use in Europe and America and they were universally satisfactory. It appeared to him that the present time a paper discussing to what extent motors might individually applied to machinery with economy, and the amount power required to drive various machines, was what was most desire The amount of power required by various machine tools under different conditions was not known even approximately. In a case in Newcastle in which he was recently consulted, it had been decided to place experimental motors in various parts of the shops, and practically use them as dynamometers, so as to find out how to best distribute the power. When the amount of power required for driving various machines was determined, something like a comprehensive statement as to how electric motors could be best applied to driving machinery might be made. He noted that they had before them an armature of a machine which was supposed to be representative of a class suitable for the operation of machine shops. They would notice the commutator had a great number of sections, and required considerable skill to manufacture and must be expensive. The brushes had to be adjusted carefully, otherwise there would be sparking. In the case of overload there would also be sparking. It was obvious, therefore, that such machines required considerable attention. He was of the opinion that simpler electrical machines should be constructed for use in machine shops. He would recommend to their attention the properties of three-phase motors. In the smaller sizes there was no collector or commutator to the armature, and the winding, instead of being several hundred conductors, as in the present case, consisted of thirty or forty copper rods having the ends joined together with a circular copper ring. The voltage in a multi-phase armature was exceedingly low, rendering liability to burn out or injury very remote. Such machines could be put in any convenient spot and perform all work without any inspection other than that required by the bearings. Multi-phase generators were also much simpler than machines of the class before

them. The collector consisted of but three rings, and there could be no such thing as sparking, no matter how much the machine was overloaded. It seemed obvious, therefore, that much the greater future was open for the use of multi-phase machinery in mill work than for the use of commutating machinery. He would further point out the great flexibility of the multi-phase system, *i.e.*, that by the use of suitable transformers power might be transmitted to any distance with comparatively little cost of copper, so that in case power was temporarily required in places remote from the generators, it could be economically supplied. He would also point out in the case of three-phase power plants for the same effective voltage between lines, the weight of copper required for the same efficiency was three-quarters that required for continuous currents.

Mr. R. H. Tweddell said he had read with great interest Mr. Mountain's paper, and he for one did not agree with the previous speaker (Mr. Broadbent) that it was unnecessary to give the elementary information which he gave in the first part. It might not be necessary for electricians, but to a mechanical engineer who had to read up this subject it was of considerable assistance. He, however, thought it was a pity Mr. Mountain had not gone a little more closely into the manner in which he proposed to apply this electric power to machines in the workshops. He had been interested all his life in the transmission of power, and he thought electrical engineers omitted to give due credit to the centralisation of power which had already been so successfully done by, amongst others, their distinguished townsman, Lord Armstrong. The economical advantage in having a central prime mover was never more clearly demonstrated than in hydraulic transmission, which system had, of course, a great many points in common with electrical transmission, with certain features in favour of the former. Of course there were some points where electrical transmission could not touch the hydraulic at all, more particularly in the matter of accumulating power. If they were to put the question as between the two in the way of distribution they must decide on economical grounds in favour of the hydraulic system, which could exert an enormous power on an emergency, and required at the same time only a small prime mover. In any comparison of electrical transmission and that by shafting they should eliminate the prime mover altogether, for an economical prime mover would be equally well applied to one as to the other. If the prime mover was the steam in both cases they could only credit electrical transmission with the saving, if any, due to substituting

dynamos, cables, and motors in place of the shafting driving the same machines He quite admitted that if the owner of any large engine works were told by an ordinary engine builder that his engine was consuming 15 or 16 lbs. of coal per horse-power, and that he should take the engine and boiler out and put in one that would only consume 1½ lbs. per indicated horse-power, it was extremely doubtful if the proposal would be entertained. But if Mr. Mountain or any electrical engineer makes a proposal to put down electrical machines, and said he must have an economical and new prime mover, say, of the compound or triple expansion type, then the owner seemed to see it in another light, and the electrical transmission got all the credit. What he should like Mr. Mountain to tell them about was the economy of electrical transmission apart altogether from the prime mover. He was quite prepared to be told he was old-fashioned, but when they were informed that in a machine like the dynamo exhibited, the bearings did not require taking up at all, that they had run ten years and might run to eternity without ever being taken up, he wanted to know why a bearing carrying an electrical load should run any longer or better than a properly constructed bearing under ordinary conditions? Mr. Mountain, however, made no such claim for the dynamo itself. He said it would burn up, which he thought much more likely if there were too much work put upon it, and this seemed to emphasize what had already appeared to him (Mr. Tweddell) the weak point in the present form of dynamos, namely, the brushes and commutators, to which he understood Mr. Mountain's remarks to refer. What he wanted to find out was the best way electricians would recommend to reduce these great velocities to a manageable velocity at the point of their application to machine tools. The average countershaft might be taken to run at 100 revolutions in a minute; but he took it that these dynamos ran from 800 to 1,000 revolutions per minute. The other day he had occasion to ask this question, and he was told that they would put a 5 feet pulley on the machine without extra charge!—connect this by a belt to a drum 8 inches or 6 inches diameter on the dynamo. This would mean a large increase in the cost of machine tools, and as regarded countershafts he would point out that they had, as a rule, no room to put a large pulley between the countershaft and the wall. He had heard people suggest that every machine should have its own dynamo. That would be one way of getting over it, and he was disposed to think that would be, at all events for large tools, or sub-sections of small tools, the best solution. He agreed with the reader of the paper that if a properly designed worm

gear was used that it would in many cases be a good way to do it. If, however, they did away with belting and its somewhat exaggerated evils, and used worm gearing, and the man gave too heavy a cut, the chances were he would stop the lathe, as the worm gearing could not give or slip. What would happen then? Either the lathe or the man would go to pieces. He should think if Mr. Mountain would give them a little more information on this head it would be extremely advantageous to the meeting. He thought there was an enormous field open for these electrical appliances. He was equally willing to own he had been a long time in seeing it, but like every other system it was apt to be overdone at first by enthusiasts, and before going head over heels into its application it would be well to see where the real weak spots in the present system were, how much due to defective prime mover, how much due to defective transmission, and how much due to the machine tools themselves. Otherwise an owner of works might throw away a great amount of capital to meet these alterations, and then not be appreciably better off. It would require to be done in connection with hydraulic transmission, for it was only the work which hydraulic machines could not do that would be better done by electricity. The two powers together should form a perfect economical application for labour-saving appliances. In no other way could they meet foreign competition except by machine tools, and there was no way to save cost in the works except by the use of economical appliances. They wanted to get a step further in this direction with the aid of the electrical engineers. From the remarks made by Mr. Parshall there seemed to be a great advantage in the multi-phase system. If it abolished many of the delicate details they saw on the dynamo exhibited, and if there were no brushes to get out of order, and if, as he took it from what Mr. Parshall said, these machines could be run for some time 75 per cent. above its power without injury to the motors or doing any damage, then a decided advance seemed to have been made. Mr. Mountain might also supplement his paper in regard to cables, by giving the cost in addition to the information about conductors, so that they might make comparison between hydraulic or electrical transmission and shafting. The author need not give it in miles, but give the cost per yard, and confine himself to the ordinary distances met with in shipyards and engine works. He (Mr. Tweddell) would, on the other hand, be happy to give him the cost per yard of hydraulic mains for comparison.

Mr. L. NEWITT congratulated Mr. Mountain upon his paper, and said he considered it had filled up a gap left by the papers read before this and other kindred institutions. In this paper the ordinary engineer was able to grasp the meaning and value of practical electrical units without a tedious study of text books. In addition to this they had illustrated machines and systems for electrical transmission of power brought up to date. There were a few points, however, which he should like to raise. In the table giving the efficiencies of motors, would Mr. Mountain please say if these efficiencies were taken at full load? If so, what was the efficiency at half load? To make this table more complete it would have been of great use to give the speed of each motor, because they knew the speed was very high, exceeding in most cases 1,000 revolutions. Now, shafting runs at about 150 revolutions per minute, and to apply motors to shafting, there must be applied a reducing gear which absorbed from 15 to 25 per cent. of the power as pointed out in the paper. Taking this loss at 20 per cent., the loss in dynamo 10 per cent., the loss in motor 20 per cent., and the loss on leads 5 per cent., they had a total of 55 per cent. loss on power delivered by main engines in transmission to machine tools. Taking for comparison the case of ordinary belting and shafting which had been properly laid out and kept in good order, the losses due to each would average about 10 per cent., thus making a total loss during transmission of 20 per cent. That might seem very low, but from data which had been collected that seemed to be very near the mark. As an example of easy working shafting he had under his notice lately three cases where 100 yards of shafting 3 inches diameter could be easily set in motion by two men hanging on to a 6 feet pulley, and unless that could be done the shafting would have to be overhauled and set more correctly. The total waste of power in that shafting was found to be from 6 to 10 per cent. With reference to belting the following points had been noted :—(1) Tight belts should be avoided wherever possible, as they were found to absorb a considerable amount of power. (2) Belting wherever possible should be run horizontally. (3) The centres between the shafting connected by belting should not be less than 30 feet. (4) The life of an average belt under ordinary conditions might be taken at twenty years. Judging from the foregoing figures, viz., where belting and shafting were used 20 per cent. loss, and where electric motors were used 55 per cent. loss, it appeared that in an ordinary works electric motors for general application were at present out of the question. But if they took a unique case, such as where ten engines of 25 horse-power were spread around instead of two or three large engines fixed near to their boilers, then it was quite possible to show by

the aid of condensation, extra enginemen, extra boilers, and other causes, a material advantage in using electric motors. Plate XVIII. illustrated a system of wiring for shops, showing all leads connected together. Why not earth the terminals of all motors, and thus save at least one-third of the cable? When dealing with the design of dynamos, Mr. Mountain had recommended that all field magnet coils should be fixed as high as possible above bearings and main shafting. This he (Mr. Newitt) would particularly like to call attention to as he knew of two cases where field magnets, being placed low down had, after a time, given out owing to the oil saturating the insulation. Now, with reference to the works with which Mr. Mountain is connected. It would be very interesting if Mr. Mountain could give them some idea of the saving due to electrical transmission, and that due to the improved engines and boilers which had replaced the old ones. Having seen both plants he (Mr. Newitt) would conclude that the saving in coals was due rather to the new engines than to electrical transmission. It seemed to him that the real fields for electric motors commenced with long lengths of steam piping, such as were sometimes required in shipyards and mines, owing to the condensation in steam pipes and other causes which had already been so plainly pointed out both in Mr. Mountain's and the President's (Mr. Richardson) papers. For dockwork and outdoor cranework, electric transmission would be more easily applied to the various pumps and cranes than other methods of transmission. Also there was no doubt as to increased safety from fire in cotton and flour mills where inflammable material was floating in the air ready for ignition by sparks which could be obtained from nearly all belts when running in dry places. Some information upon this latter point would also be of great value.

Mr. Wm. Boyd said it was not often he had an opportunity of attending these meetings; but being present, he had a sort of feeling he should like the members to be alive to the fact that he was still in existence. He admitted to very great ignorance of the subject discussed there that night, but from the point of view of the application of economy to their workshops, the subject was one that had commended itself to him for a very long time. It was brought more strongly before them than ever by the inaugural address of Mr. Richardson at the beginning of the session. There was, no doubt, that the electrical engineers of this and other districts ought to be much indebted to Mr. Richardson for his notice of the subject in his inaugural address, for it gave an immense impetus to the discussion of a matter which was very

wide in its ramifications, and, he might say, had enormous possibilitie before it. Perhaps it might be known to some of them that the questio of what they might call "economy of production" was one of his littl hobbies, and the necessity for that economy of production was none th less evident now than it was when urged in that room some ten years ago The price that they could obtain for the produce of their works wa reduced to a minimum, and, as far as they could judge, with very littl prospect of improvement. Therefore, if works were to be carried on wit the most moderate degree of success, it was necessary to look in othe directions and see where any economy in production or carrying on th work in the workshop could be carried out, and if this electrical di tribution of power was directly or indirectly the means of inducin manufacturers to modify or remodel their establishments, and if were established on a sound basis (as had been said by son speakers and pointed out, he thought, in this paper) that t capital expended could be recovered in three or four years it wou be a very attractive programme indeed. What was the weak point the comparison in this paper? He said "weak point" without wishin to be offensive. It was pointed out when Mr. Richardson called attentio to the subject in his inaugural address, and had been alluded to by M Tweddell, and it was this:—The comparison before them went upon th assumption that the different steam engines (say eight or ten in differen parts of the works) were all abolished, and the necessary power put int one highly efficient surface condensing triple expansion engine. Th was perfectly true. The advocates of this system must admit it w perfectly true, and the great percentage of their saving lay in th element; but the answer, he took it, was this: for electrical distributio they must have the most economical engine power, and they could di tribute it with very small loss (90 and 95 per cent. of efficiency). A had been justly pointed out, one of the successes of this system lay in t improvement of the motive power—the engines; but still he thought t electricians had a right to turn round upon them and say that was pe fectly true, but you cannot make use of that economy except by so system of electrical distribution. The great difficulty, or one of the gr difficulties, which he saw had to be got over, was that alluded to by M Tweddell, the reduction of the speed of the motors, running at 1,8 revolutions, down to the ordinary number of revolutions required by ordinary lathe or planing machine. Mr. Mountain had alluded in h paper to worm gearing. He had not seen many instances of that in h own practice; but there were planing machines driven by worm gea

which might perhaps be successfully followed, but he saw great difficulties in a very large pulley attached to the ordinary countershaft, for it was either hung by a bracket, something like 2 feet long, from the inside of the girder, or attached to a bracket on the wall, so to put a very large pulley on a bracket of that kind could not in fact be done. They would either have to remove all the shafting or make some other arrangement; but he thought it was one of the problems to which those who were devoting themselves to this subject would have to apply themselves. There was no doubt, in his opinion, that there was a great field for this subject which had been brought before them on this occasion. If ordinary engineering establishments were to live at all in times like these it could only be done by reducing their working expenses to the very smallest possible point.

Mr. J. H. HOLMES said there were only one or two points he begged to mention, and one was with reference to the reduction of speed of the motors, so as to make them available for working machinery. One way of doing this, which had not been mentioned yet, was simply to have the motor made of a rather larger size. There was no difficulty in making a motor to work at as slow a speed as they could wish for, if only they would pay for it. Another point was about the bearings. The question was whether they need be adjustable or not. A dynamo was very different to a steam engine in that the motion was not reciprocating motion; it was simply a plain rotatory motion, and there was very little pull upon the bearings, merely that due to the belting, but that pull was always in the same direction. Consequently, as he said, the bearings of the motors were under very different working conditions to the bearings of a steam engine.

The following communication on the subject from Mr. G. T. Duncan was received :—

NEWCASTLE-UPON-TYNE,
February 12*th*, 1895.

DEAR MR. DUCKITT,

The interest evinced in the recent papers here by Mr. W. C. Mountain, and elsewhere by Mr. Alexander Siemens, on the "Electrical Transmission of Power," afford ample evidence of the paramount importance attached to the subject by engineers generally. In connection with the papers, to which I have been privileged to listen, I have observed that comparisons have been made only with steam engines, which, in most cases, are apparently of ancient design and construction, and ill-

adapted to the work in which they were engaged during the tests, thus showing an abnormal and unreliable coal consumption per indicated horse-power, while on the other hand the electrical plant has been of modern construction, and probably under the actual supervision of the manufacturers or their experts. If the most desirable practice of indicating steam engines periodically were adopted to a greater extent than prevails at present, I feel sure that much of the wastefulness, to which reference has been made, would be avoided. In considering the paper under discussion, we are apt to infer that the steam engine is the only rival of the electric motor, because, so far as I am aware, no particular reference has been made to any other. I feel justified therefore in asserting that there is another form of motive power, which, during the past few years, has been extensively and successfully adopted, not only in small manufactories where, for intermittent work, the economy is immense, but also in large engineering establishments and shipyards in the North of England and elsewhere. Need I say that I refer to the gas engine, which possesses many of the advantages claimed by the advocates of the electric motor? The plan hitherto generally adopted has been to gradually apply such engines of 16 to 30 nominal horse-power to the various sections of a large works, in close proximity to the centre of the main shafting. A complete stoppage of the works through mishap is practically impossible. Each engine is entirely independent, and is available for work at almost any moment, while overtime or night-shift can be worked in any department with very little expense, and I believe that apart from the greater convenience and saving of space, a substantial economy is effected, when using towns gas, which is of course moderately cheap in this locality. In some towns, however, producer gas is applied, which is made from either anthracite coal or coke, and it effects a much greater saving, as gas, sufficiently good for the purpose, can be provided at a cost of about 3d. per 1,000 cubic feet. I have recently been provided with some figures showing the cost of working three of Tangyes gas engines (with gas producing plant) indicating about 140 horse-power, and find that, using *coke* as fuel, the consumption is only 1·05 lbs. per indicated horse-power per hour. Some later tests show an even greater economy, and with anthracite coal as fuel, it is safe to undertake a consumption within 1 lb. per indicated horse-power per hour. These gas engines replaced steam engines of fairly modern construction, which were destroyed by fire. The immense saving will be apparent when it is stated that the total cost of running the steam engines for three months was £175, as against £51 in the case

of the gas engine, giving a greater output for a similar period. I feel that we are all indebted to Mr. Mountain for the very lucid, exhaustive, and interesting paper, which he has provided for our consideration, and hope it may prove an incentive to other members to lay before us the results of their tests or experience with any of these powers from a user's point of view only. It may be of interest to add that gas engines with single cylinders are now being constructed to indicate about 160 horse-power, and that several similar engines are in hand of 120 indicated horse-power each, for driving centrifugal dock pumps direct in a neighbouring town. In conclusion, I may state that the recent rapid extension of the adoption of gas engines is also due to the enormous reductions that have taken place in first cost during the past few years, and to their now recognised simplicity and reliability.

Yours faithfully,

GEO. T. DUNCAN.

The discussion was adjourned.

ON THE APPLICATION OF THE ELECTRIC ARC TO MACHINERY AND BOILER REPAIRS, ETC.

By HENRY FOSTER.

[Read before the Institution, in Newcastle-upon-Tyne, on February 12th, 1895.]

At the present time there are two principal systems of electric welding in successful operation, and each system possessing special features which render it more particularly adapted for certain classes of work than the other. Firstly, we have the Thomson-Houston system, in which the heating effect induced by the resistance to the passage of the electric current through the articles to be welded together, accompanied by a certain amount of pressure between the parts thus heated, is made to produce the required weld; and, secondly, we have the Benardos or arc system, in which the article to be operated upon is made to constitute one pole of the electric circuit, while a carbon pencil attached to a portable insulated holder, and held by the workman, constitutes the other pole, the electric arc—which is the heating agent of the process—being struck between the two poles thus formed. When steel or iron is being welded it is usual to make the carbon the negative pole, and the steel or iron the positive pole; but for other metals the poles are sometimes reversed. In welding lead, for instance, it is usual to work with the carbon positive.

In this paper the writer proposes to confine his remarks and illustrations exclusively to the Benardos or arc system of welding—which, having been considerably improved in detail during the last few years at the works of Messrs. Lloyd & Lloyd, Birmingham, at Newburn, and elsewhere, is now more generally known as "the improved Benardos system"—and more particularly to the application of this system to repairs of machinery, etc., done under his supervision.

The method of working is a very simple one, and is practically identical in all cases. The only difference between the methods of

working adopted by Messrs. Lloyd & Lloyd, and those adopted a Newburn, is in the construction and arrangement of the resistances, an may be taken as generally illustrative of the methods adopted elsewhere and shortly described as follows :—

At Messrs. Lloyd & Lloyd's, Coombs Wood Works, the welding pla is arranged as illustrated by Fig. 1, Plate XLV. Here an ordina lighting low tension continuous current dynamo is used, to the termina of which a battery of Benardos accumulators is connected, and into whi the current flows continuously. When the welding circuit is closed, current flows from the dynamo and accumulators through a la regulating resistance, and by these means a discharge equal to ab twice that of the capacity of the dynamo is available. In parallel w the terminals of the dynamo or battery as many welders or weld i machines as may be desired can be connected, and every welder is *ab* independently to vary his current and pressure to suit the work in ha at the moment. One terminal of each welding system is connected b means of a flexible cable to a carbon pencil held in an insulated holde which is in turn held by the workman, while the other terminal of th system is connected to the table on which the work lies, or to the wor itself. The special advantage of this arrangement of resistances an accumulators is that it admits of wide limits of variation of current an pressure to suit the different classes of work which may be in progres and in the installation at Coombs Wood, arrangements are made so th the works, offices, and foremen's houses are lighted, motors are drive and the electric welding plant is supplied with current all from the san system of mains simultaneously.

In cases where the current and pressure required for the work *in* progress are practically constant, and only welding is required to be done for the time being from the circuit, it is possible to work effectively without accumulators, providing large resistances are adopted, and this latter method of working, illustrated by Fig. 2, Plate XLV., is that in use at Newburn.

The efficiency of the method of working, illustrated by Fig. 2, is not so high as that illustrated by Fig. 1., because during the time that welding is not being done the outer circuit is not closed, and no current is passing, consequently the whole plant is running light ; but in a welding installation this defect may in a great measure be obviated by arranging two or sometimes three welders in the same circuit, and so arranging matters that when one man is welding the other one is dressing his work and making preparations for his turn.

In any case, however, the method illustrated by Fig. 2 has the advantage of decreased first cost, and is more portable, and it becomes a matter of £ s. d. with each individual user, as to whether the method of working as illustrated by Fig. 1, with its greater first cost and greater efficiency, or the method illustrated by Fig. 2, with its less first cost but proportionally less efficiency, is most suitable for the particular work to be done; bearing in mind that method No. 1 admits of a greater range of variation of current and greater length of arc being obtained than with method No. 2, and that with the lighter classes of work it is essential to use as long an arc as possible, because the heating effect is more regular and better distributed.

The real object of this paper, however, is not to discuss the relative merits of the different methods of arc welding under special circumstances, but to show by a series of illustrations:—(1) What has been done by the method of working illustrated by Fig. 2; and (2) to explain to those interested the simplest and cheapest method of doing similar work, which the writer's experience would suggest.

General Machinery Repairs.

Fig. 3, Plate XLVI., represents one of the eccentric rods of the reversing engines which drive the plate mills at Newburn, and which was accidentally broken as indicated on August 13th, 1891. The engines which had only recently been erected were being tested under steam (with a view to having all in readiness for the official inauguration ceremony in connection with the opening of the mills on August 15th) when, owing partly to the sand and dust incidental to a new works, and partly owing to the negligence of the greaser, one of the eccentric straps seized, and the eccentric rod bent and broke close to double eye neck.

The eccentric rod being of steel, and the position of fracture so awkwardly situated that it could not be readily welded in the ordinary way, it was decided to straighten the bent and broken rod and electrically weld it. This was done, and the engine with repaired eccentric rod attached was running again under steam at six o'clock the following morning. The eccentric rod as originally welded is still working, and has never since given the slightest trouble, although the engine in question has rolled every plate which up to the present has been made at Newburn.

Fig. 4, Plate XLVI., represents a slot-link for the reversing engines originally supplied to drive the live rollers of plate mill previously referred to, and which, while working, broke as indicated and stopped the mill. The broken pieces were placed together and electrically welded at the points of fracture, after which the link was fitted and erected, and

the engines with repaired slot-link were running again within one hour from the time of original breakdown. This slot-link continued to work for over twelve months without trouble, and until the engines were eventually removed.

Fig. 5, Plate XLVII., shows one of the steel roughing rolls for a bar mill, which under normal conditions works with heavy draughts on hard steel, and by which the wobbler end had been worn, as indicated, until the coupling box turned round without driving the roll, thus rendering the roll useless. The roll, which weighs over 50 cwts., was taken out and the worn portions electrically welded up again to original size. The whole operation of taking out, welding, and putting in place again, only necessitated the mill standing for twenty-four hours. The welded roll has now been running for about six months, and although the wobbler is again wearing out, it is satisfactory to know that when it is again worn so that the coupling box refuses to drive, the welding can be repeated again and again if necessary.

Fig. 6, Plate XLVII., shows one of a pair of cast steel helical pinions each weighing over 6 tons, for a large reversing plate mill. These pinions had to be taken out and the spare gear substituted, owing to wobbler ends being worn as indicated by the constant reversing of the mill. With reversing mill pinions there is often a difficulty experienced in casting them of the exact hardness most suitable for the work. Either they are cast too hard, causing the pinion teeth to break before the wobbler ends are worn, or, as in this case, the wobbler ends are worn while the teeth are left perfect, owing to the steel being too soft. These wobbler ends were electrically welded up to the size originally made when new, and the pinions put to work again on January 28th, 1895, and although since being welded they have not been working long, yet, there is no need to anticipate trouble from the welding.

Fig. 7, Plate XLVII., and Fig. 8, Plate XLVIII., show two different sizes of live rollers for carrying the plates at the front and back of the plate mills to which they respectively belong, and, owing to the washing of plate scale into the bearings during the operation of rolling, the bearings in several instances had been worn and considerably reduced in diameter, as shown by dotted lines; and under ordinary circumstances this would have necessitated new live roller shafts. Instead of providing new shafts, the worn bearings were electrically welded up to sizes sufficient to allow of their being turned to the original finished diameter. They were then machined and put in place again; six of the larger type of shafts, represented by Fig. 8, having been repaired in the manner indicated during the last New Year holidays.

Fig. 9, Plate XLVIII., shows the crank shaft of the small screwing engines fixed on the top of the plate mill housings. The object of these engines is to turn the housing screws, and regulate the distance between the rolls, and thereby determine the amount of draught at each pass of the slab. The original eccentrics on these crank shafts were in halves and keyed to the shafts in the usual way; and so long as this arrangement existed, constant trouble was experienced, either due to the eccentric keys or bolts coming loose, or to the eccentrics breaking. It was therefore decided to electrically weld new steel eccentrics to the old crank shafts, and this was done as follows:—Rough slabs of steel were smithed to the shape shown by Fig. 10, Plate XLVIII. These slabs were then heated red hot, and clasped round the shafts, and the V-shaped recesses (*a*) (*a*) electrically welded up to form the complete eccentric in each case. The shafts were afterwards centred in a lathe, and the eccentrics turned to finished shape in the usual way adopted when turning eccentrics on a solid shaft. Two exactly similar crank shafts had eccentrics fitted in this manner, and neither of them has given the slightest trouble, although the first one has now been working for nearly twelve months.

Fig. 11, Plate XLVIII., shows a small locomotive axle, to which double eccentrics have been fitted, exactly in the same manner as above described.

Fig. 12, Plate XLIX., represents in detail the draw-back piston and piston rod of a "Davy" 2,000 tons hydraulic forging press, illustrated in side and end elevation by Figs. 13 and 14, Plate XLIX. When working, it was found that the draw-back piston rod *a b* was 10 inches too long at end *b* to admit of forgemen's cutters, etc., being readily used, and as the swelled portion of piston rod at end *b* was only $9\frac{1}{4}$ inches long; it did not admit of being screwed further up, and at the same time suit existing nuts when 10 inches had been cut off ends of piston rods. The excess length of 10 inches was, however, cut off, after which bosses were electrically welded on to the $4\frac{1}{4}$ inches diameter shaft ends of sufficient size to admit of their being turned as before to $4\frac{3}{4}$ inches diameter and $9\frac{1}{4}$ inches long. The piston rod ends were then screwed to suit old nuts and afterwards erected, and the press worked as before without any trouble being experienced.

Fig. 15, Plate XLIX., shows a shaft with flange coupling keyed on one end. The continual reversing of the engine to which this shaft belonged, together with the heavy nature of the work done, started the keys, which in turn damaged the edges of their key-beds, and also the bed of shaft coupling, as illustrated. The damaged parts were welded up again, and

the bed of the shaft coupling turned, new key-ways cut, and coupling keyed on as before. This example is only one of several shafts which have been treated in the same way—many of them being done *in situ*, and always with excellent results.

Fig. 16, Plate XLIX., shows a cogging mill live roller, the outer case being of cast steel with forged steel central shaft. The object of these rollers is to carry the hot ingots, weighing in some instances upwards of 7 tons, to and from the main rolls during the process of cogging; and owing to the heavy nature of the work, especially in the immediate neighbourhood of the main rolls, the cast steel outer cases frequently broke—mostly in the corners as indicated—leaving the central shafts unaffected. Several of these broken outer cases were electrically welded and again put to work, and although some of the electrically welded rollers which occupy favourable positions furthest away from the main rolls have been at work nearly three years without fracture, yet it was found that those electrically welded rollers which occupied the most unfavourable positions nearest the main rolls continued to break; sometimes at the weld, and sometimes through the unwelded parts, without distinction; and the trouble was not overcome until solid forged steel live rollers had been substituted for the original cast steel cases in the immediate vicinity of the main rolls.

Fig. 17, Plate XLIX., represents another type of live roller, of which there are six altogether, forming an extension of live roller system for carrying the hot slabs from cogging mill to hot bloom shears. Owing to an error in original sketch dimensions, the central shafts of these live rollers were all made and finished $2\frac{1}{8}$ inches too short at the ends where mitre driving wheels are keyed on, thus leaving very little length of shaft to which the mitre wheels could be keyed. The extra length of shaft required in each case was electrically welded on by "building up" in the usual way, and the wheels keyed upon the electrically welded portion as shown. These shafts have been at work for about three and a half years without trouble, having carried all the hot slabs required in the manufacture of plates since the mills were started.

Apart from the general work done at Newburn by this process in the repair of slightly defective steel castings, many other instances might be cited where repairs of a similar nature to those already described have been done; such, for instance, as welding in the teeth of cast steel wheels which have been broken out while working, without removing the wheels from their shafts, but one more example must suffice before proceeding to treat of the application of the process to boiler repairs.

Fig. 18, Plate XLIX., shows a steel hydraulic ram, forming part of a Wicksteed's patent hot bloom shears. The object of this ram, which works automatically with the shears, is to hold down the crop ends or the hot slabs, and prevent them from tilting up while being cut, and afterwards falling back upon and doing damage to the live roller table. The end of this ram when in use rests immediately upon the bright red hot slab, being, of course, exposed to the full heat of the slab at the time; but just previous to, or after the slab has passed, the cooling water is turned on to cool the cutting parts, and those parts of the machine in the immediate neighbourhood. Thus the end of the ram is alternately exposed to the heat of the slab and the cold water used for cooling purposes, and was originally circular in plan and too far away from the cutting edges of shear blades to prevent the short crop ends tilting up and jamming between the shears apron and the ram. The ram was therefore taken out and electrically welded to form shown, so that now the foot of ram is rectangular in plan, and since being welded has worked under the conditions named for about two and a half years without giving the slightest trouble.

Steam Boiler Repairs.

The first application of the process of electric arc welding in connection with steam boiler repairs at Newburn, was made in September, 1891, upon a boiler supplied by Messrs. Joseph Booth & Bros., Rodley, near Leeds, for driving one of their 35 tons overhead steam cranes, and shown in outside elevation by Fig. 19, in sectional elevation by Figs. 20 and 21, and in sectional plan by Fig. 22, Plate L.

This boiler, which is eminently adapted for raising a large volume of steam in a limited space, is provided with an outer casing lined with firebrick, built in the form of flues, which completely encircle the outer shell of the boiler, so that the hot gases from the fire are compelled to pass entirely round and in contact with the outer shell before escaping at the chimney.

The defect, which was situated at *c* (Fig. 20), where the outer shell of boiler is riveted to bottom plate, had originally existed as a leak, which, not being visible from the outside, had caused considerable corrosion at this point before it was discovered, and when the corroded parts had been cut away to full plate thickness, a hole was left in the outer shell, 5½ inches long by 3½ inches deep, and extending round the bottom flange of outer shell in the immediate vicinity—a somewhat difficult place to fix a patch without removing the internal firebox.

leaks were stopped, and no further trouble has been recorded during the eight months which the boiler has been running since the work was done.

Fig 26, Plate LII., is a longitudinal cross sectional elevation and Fig. 27 an end elevation of Lancashire boilers, each 28 feet long by 7 feet 6 inches diameter, four of which, numbered respectively 5, 6, 7, and 8, owing to defective construction of flues and furnaces, have given considerable trouble in working. In these boilers (which were constructed for a working pressure of 100 lbs. per square inch) the different lengths of flue, instead of being welded and made truly cylindrical, are each formed with single riveted lap joints below firebar level, and the alternate lengths made to break joint at *a* and *b* (Fig. 27), and joined together by Bowling hoops as shown.

Where the lap joints of flues make joint with Bowling hoops they are drawn to a fine edge, and with the expansion and contraction of the flues under pressure a heavy stress is brought to bear upon the Bowling hoops in the immediate neighbourhood of the joints, with the result that the Bowling hoops crack in the corners as shown at *a* (Fig. 28, Plate LII.), through a certain portion of their circumference immediately opposite the longitudinal joints in the flues—the cracks in every instance being in the corner adjacent to the lap joint—and although not immediately dangerous the working of boilers had to be discontinued owing to excessive leakage.

To fit new flues, or even to fit new joint rings in place of Bowling hoops, would have necessitated the boiler fronts being taken off, which, irrespective of the expense, in this case implied that part of the working plant must stop for want of steam.

The trouble commenced with No. 8 boiler in September, 1893, and in the first instance was confined to one boiler only, and one Bowling hoop, the crack being 13 inches long, and extending about even distance on either side of flue joint. It was proposed to electrically weld the defect *in situ*, but before doing so the Boiler Insurance Company were requested to allow their inspector to attend and witness the process of electric arc welding as carried on in another department of the works, and satisfy himself as to the feasibility of the proposal; this being done, the boiler was electrically welded as follows:—A pair of ordinary electric cables were procured, of sufficient length to reach from the electric lighting dynamo to the boiler, and of sufficient size to carry the necessary current. One end of cable No. 1 was attached to the positive terminal of the dynamo, and its other end to the boiler manway cover. While one end of cable No. 2 was attached to the negative terminal of the dynamo, and its other end to the resistances, which in this case, as in

others already cited, consisted of a number of ordinary arc lamp resistance coils. From the resistance coils a flexible cable was carried over the boiler front and into the boiler flue, and terminated at the carbon holder held by the workman. The crack was then gouged out, and welded up by inserting small nuggets of mild steel and melting them under the influence of the electric arc, and gradually incorporating the new material with the old in the vicinity of the line of fracture, the form of finished weld being shown at *b* (Fig. 28), where the shaded portion indicates new material added. The welding operation occupied about five hours, and, when completed, the boiler was tested under water pressure to 150 lbs. per square inch, and found perfectly tight, and steam was raised in this boiler on the following day.

Exactly the same trouble as that above recorded was experienced with Nos. 6, 7, and 8 boilers in October, 1893, the crack in Bowling hoop of No. 8 boiler being at opposite side of flue to that previously welded.

No. 6 boiler was electrically welded on Saturday, October 14th, No. 7 on Sunday, October 15th, and No. 8 on Monday, October 16th, and after being tested under water pressure, as before, were all working under full steam pressure at 6 a.m. on October 17th.

In the case of No. 8 boiler the exact time occupied in welding the crack (5 inches long) was recorded as follows :—

Boiler blown off at	1·30 p.m.
Commenced to electric weld at	3·0 ,,
Welding completed at	4-30 ,,

All the boilers continued to work almost without interruption and without trouble being experienced until August and September, 1894, when very heavy firing was necessary to meet the increased demands for steam, and it was again found necessary to electrically weld the boilers as follows :—

Aug.	11th.	Electrically welded	Bowling hoop of	No. 5	boiler	crack,	4½	inches long.
,,	12th.	,,	,,	,,	No. 6	,,	,,	11½	,,	
Sept.	1st.	,,	,,	,,	No. 6	,,	,,	3½	,,	
,,	17th.	,,	,,	,,	No. 6	,,	,,	1½	,,	
,,	17th.	,,	,,	,,	No. 7	,,	,,	10¾	,,	*
,,	17th.	,,	,,	,,	No. 7	,,	,,	2	,,	†

* Left hand tube † Right hand tube.

In two or three instances cracks have again occurred through the electrically welded joints, but this has always been directly opposite the longitudinal seams of the tubes where fracture of original hoops took place ; and from experience gained in welding these defects and carefully noting their behaviour the writer is of opinion that by electrically

welding the Bowling hoop and tube together in the immediate neighbourhood of the junction of longitudinal seams with the Bowling hoops, and slightly increasing the total thickness at this part by building up and thereby stiffening the joint, the trouble can be entirely overcome, if this has not already been done, seeing that it has not been again necessary to weld the joints since September, 1894.

Cutting and Boring.

Another very simple application of the electric arc is that of cutting and boring metals roughly to shape, and in work of this kind the same methods of procedure apply as in all the other cases cited, viz., that the article to be cut is made to form one pole, and the carbon pencil the other pole. Under these conditions, if the carbon pencil is brought in contact with the metal to be operated upon, an arc is immediately struck between the carbon pencil and that part of the metal in contact with it at the time, with the result that the metal is instantly melted in the immediate vicinity of the arc, and may be allowed to flow away as it is melted. In this way holes may be pierced in steel, iron, or other plates with great rapidity, and by moving the arc gradually along the holes may be elongated into slits of any required length or shape at the option of the workman.

Fig. 29, Plate LII., shows a wrought iron tube sunk in the river bank and surrounded with broken slag and gravel. The object of this tube is to form a large strum from which water may be pumped at all states of the tide, and originally it was lying in stock as a plain tube without holes in side plates. The tube as shown was sent to the electric welding shop at 8 a.m., and between that time and four o'clock on the afternoon of the same day, 304 holes, each about 1 inch diameter, had been pierced through the 5-16 inch thick side plates—the actual rate when working being between two and three holes pierced per minute.

Fig. 30, Plate LIII., shows an end elevation and Fig. 31 a sectional plan of the port block of a Siemens-Martin steel melting furnace. The ends of this furnace were originally built with ½ inch steel binding plates, placed between the furnace brickwork and the end buckstaves, and practically covering the whole of the furnace ends as shown. When the interior surfaces of the gas and air ports had been partially melted away by the action of the hot gases, and required slight repairs, the ½ inch end plates prevented the work being done without pulling down the whole of the brickwork overlying the damaged portions of the ports. If the furnace binding bolts had been released in order to take out the

the negative cable should be divided, and resistances *a a* interposed as shown, except in special cases where the cables are sufficiently long to render resistances unnecessary.

The resistances may be composed of a number of bars of iron, wound in the form of helical springs to reduce the space occupied, or, preferably, the resistance coils ordinarily used in connection with the arc lamps may be utilised and arranged as shown by Fig. 34, the only necessary condition being that sufficient resistance be interposed to ensure a steady and continuous arc at the operator's carbon *b*, and in all ordinary cases this will be obtained by a drop in the voltage of that portion of the negative cable lying between the resistances and the operator's carbon, as compared with that portion lying between the negative terminal of the dynamo and the resistances, of about 30 to 35 per cent.; or, in other words, if the pressure at dynamo be, say, 80 volts, the pressure at operator's carbon should be, say, 52 to 56 volts to ensure a steady and continuous working arc, and this will generally be obtained by interposing from 24 to 28 ordinary 3,000 C.P. arc lamp resistance coils, as shown at Fig. 34.

Of course a very much more portable and equally efficient regulating resistance may be arranged, but in the case cited it is assumed that only the arc lamp resistance coils are at hand. A short portion of the cable to which the operator's carbon holder is attached should be flexible, so as to admit of easy manipulation of the arc, and as light as possible consistent with its carrying the necessary current without undue heating.

The face and eyes of the workman must in all cases be protected; that portion of the protector covering the eyes being of coloured glass, preferably in three separate thicknesses and composed of two red pieces, occupying the back and front, with a blue piece interposed between them, for if the eyes are exposed even momentarily to the full glare of a large arc, an effect is produced upon the muscles of the eye which, though not permanently injurious or of more than a few hours' duration, is very painful and disagreeable while it lasts. The effect produced upon the face, or other tender portions of the skin by exposure to the radiant energy of the arc, for any length of time—although not felt at the time of exposure—is similar to that produced by a very severe sun-burn, and also painful when an attempt is made to wash the parts with soap. With these precautions taken, no trouble has ever been experienced, and the same men are now at work welding who have been associated with the process since its installation, and with such a low E.M.F. it is impossible to get a dangerous or even unpleasant shock, consequently the machine

or articles in circuit may be handled with impunity, and all the operations of welding, etc, carried on with the workman sitting or lying upon the articles being welded.

Necessary Precautions to Ensure Sound Welds.

1st. The carbons used should be "uncoppered" and of one uniform quality, sound and hard, and having a metallic ring when struck, and must burn with little or no dust deposit, otherwise the finely divided carbon deposited on the weld may be absorbed by the metal, which will thereby be rendered brittle. 2nd. When "building up," the metal introduced into the weld should be as nearly as possible of the same composition as that of the article to which it is welded, and the workman should remove the slag formed on the surface of the weld from each layer added before commencing to add another one. In cases where the part to be "built up" projects above the neighbouring surface (as for instance a wheel tooth), each layer of material added should be retained in position and prevented from flowing away while in a molten state, and this is best done—previous to the addition of each layer—by forming a ridge of finely ground gannister clay round the circumference of the layer to be added. 3rd. When the metal in the vicinity of the arc has been under the action of the arc for a short space of time, the heat gradually extends by conduction to the metal in the neighbourhood of the part operated upon, whereby the resistance of the metal to the passage of the current is increased and in consequence admits of a longer arc being obtained than under conditions where the metal in the vicinity of the part operated upon is not so heated, and the workman should always endeavour to obtain these conditions of heating of the surrounding metal, and to finish off each layer under the action of a long and steady arc, so as to ensure the gradual solidification of the metal added, and its subsequent annealing by the gradual radiation of the heat from the part operated upon, when the carbon is eventually withdrawn and the arc broken. 4th. In all cases where it is possible to do so each layer of new material added should be hammered immediately the carbon is withdrawn and the arc broken; and where this is not possible, the withdrawal of the carbon, and breaking of the arc should be gradual, for reasons already stated.

Quality of Work done by the Benardos Process.

In order that the capabilities of the Benardos process of electric arc welding, in relation to the quality of work done, might be placed beyond doubt, Mr. Henry Lea, the well-known electrical engineer, of Birming-

ham, was requested by Messrs. Lloyd & Lloyd to conduct for them an investigation in conjunction with Messrs. David Kirkaldy & Son, of London. For this purpose, two hundred and ten bars of varying thicknesses and qualities of iron and steel were electrically heated and welded by ordinary workmen (not trained smiths), and, together with fifty bars welded by good engine smiths in the employment of another firm out of a coke fire in the usual way, were submitted to Messrs. Kirkaldy to be tested. The results, as reported by them, will be found in the following Tables I. and II. The "average ratio of weld to solid" of the one hundred and fifty electrically heated iron bars equalled 85·5 per cent., and of the sixty steel welds 80·8 per cent. In every case ten welds of each size were tested. A comparison between the table of results obtained from the hand welded bars and those which were electrically heated will show that in every case the latter give a higher "ratio of weld to solid" than the former. In other respects, also, the comparison is usually favourable to the electrically heated bars. (See Table II.) These experiments are believed to be the first attempt to demonstrate scientifically the value of the arc as a heater of iron and steel for welding purposes. It must be remembered, however, that the results shown were obtained by comparatively unskilled hands, and could be materially improved by continuous practice.

The economy of arc heating in the manufacture at Coombs Wood and elsewhere of various articles is established beyond doubt.

TABLE No. I.

SUMMARY OF RESULTS OF EXPERIMENTS TO ASCERTAIN THE TENSILE STRENGTH, ETC., OF 10 ELECTRIC WELDED BARS OF EACH OF THE UNDERMENTIONED SIZES AND BRANDS, COMPILED FROM THE DETAILED REPORTS.

Material and Brand.	Nominal Size.	Description.	Ultimate Stress per Square Inch.	Contraction of Area at Fracture.	Extension in Ten Inches.	Ratio of Weld to Solid.
	Inches.		Lbs. Tons.	Per Cent.	Per Cent.	PerCent
LOW MOOR IRON.						
Iron, Low Moor	2 × 3/16	Mean of Solid ...	58,417 = 26·1	42·3	19·5	—
" "	"	" Welds...	47,367 = 21·1	17·3	7·3	81·1
" "	2 × 1/4	Mean of Solid ...	55,537 = 24·8	45·7	22·9	—
" "	"	" Welds...	48,429 = 21·6	20·9	8·1	87·2
" "	2 × 5/16	Mean of Solid ...	53,237 = 23·8	46·0	24·1	—
" "	"	" Welds...	48,890 = 21·8	20·7	9·7	91·8
" "	2 × 3/8	Mean of Solid ...	55,363 = 24·7	41·7	26·7	—
" "	"	" Welds...	49,517 = 22·1	16·7	9·0	89·4
" "	2 × 1/2	Mean of Solid ...	47,872 = 21·4	46·9	31·3	—
" "	"	" Welds...	46,343 = 20·7	19·2	10·2	96·8
PARKGATE STEEL.						
Steel, Parkgate, Yorkshire	2 × 1/8	Mean of Solid ...	67,846 = 30·3	57·1	22·3	—
" "	"	" Welds...	49,956 = 22·3	18·4	3·8	73·6
" "	2 × 3/16	Mean of Solid ...	57,268 = 25·6	57·2	25·7	—
" "	"	" Welds...	46,482 = 20·8	16·0	4·2	81·2
" "	2 × 1/4	Mean of Solid ...	56,730 = 25·3	57·4	27·0	—
" "	"	" Welds...	44,464 = 19·8	17·5	4·4	78·4
" "	2 × 5/16	Mean of Solid ...	54,819 = 24·5	57·1	26·4	—
" "	"	" Welds...	46,405 = 20·7	17·1	6·1	84·7
" "	2 × 3/8	Mean of Solid ...	55,932 = 25·0	54·7	26·0	—
" "	"	" Welds...	45,044 = 20·1	15·5	6·3	80·5
" "	2 × 1/2	Mean of Solid ...	54,486 = 24·3	61·2	31·5	—
" "	"	" Welds...	47,100 = 21·0	15·4	7·3	86·4
FARNLEY IRON.						
Iron, Farnley	2 × 1/8	Mean of Solid ...	53,918 = 24·1	31·2	17·3	—
" "	"	" Welds...	46,281 = 20·7	6·5	4·4	85·8
" "	2 × 3/16	Mean of Solid ...	59,207 = 26·4	37·4	18·1	—
" "	"	" Welds...	45,887 = 20·5	8·6	4·4	77·5
" "	2 × 1/4	Mean of Solid ...	52,816 = 23·6	35·7	23·3	—
" "	"	" Welds...	48,365 = 21·6	17·6	6·5	91·6
" "	2 × 3/8	Mean of Solid ...	49,005 = 21·9	49·4	27·5	—
" "	"	" Welds...	48,234 = 21·5	13·1	6·4	98·4
" "	2 × 1/2	Mean of Solid ...	49,028 = 21·9	44·7	26·7	—
" "	"	" Welds...	42,343 = 18·9	10·5	4·6	86·4
NETHERTON IRON.						
Iron — Netherton ♛ best	2 × 3/16	Mean of Solid ...	51,892 = 23·2	23·5	11·2	—
" "	"	" Welds...	44,122 = 19·7	8·6	4·7	85·0
" "	2 × 1/4	Mean of Solid ...	48,910 = 21·8	22·7	10·6	—
" "	"	" Welds...	44,995 = 20·1	10·8	4·5	92·0
" "	2 × 5/16	Mean of Solid ...	56,298 = 25·1	23·7	18·0	—
" "	"	" Welds...	40,732 = 18·2	7·0	2·2	72·4
" "	2 × 3/8	Mean of Solid ...	56,292 = 25·1	24·3	20·9	—
" "	"	" Welds...	41,064 = 18·3	5·8	2·5	72·9
" "	2 × 1/2	Mean of Solid ...	53,485 = 23·9	29·5	23·2	—
" "	"	" Welds...	41,539 = 18·5	5·5	3·4	77·7

All the welds in the above series were scarf welds, length of scarf averaging $1\frac{1}{4}$ to $1\frac{1}{2}$ inches. The results obtained from the welds of Low Moor iron, Parkgate steel, and Farnley iron are satisfactory, the principal features being absence of cinder or impurities from the faces of the scarf, and the maintenance of a fair amount of ductility at the weld, the material not being abnormally affected by the heating. Where the welds have come out low the appearance of fracture points to the metal having been either not hot enough or the thin edge of scarf having cooled ere the weld was closed by hammering. In the case of the Netherton iron there is a serious tendency to loss of ductility, the fractures showing very crystalline. As there are, however, some good welds amongst them without these objections, it would appear as if the treatment, as regards the amount of heat, had not been adapted to the nature of the iron. To judge of the full merits and capabilities of the electric welding, due regard must be paid to the individual as well as the average results. The hand or smith welded bars, which are about to be tested will afford means for an exact comparison.

NOTE.—The mean results are based upon the whole ten welds, as far as the ultimate stress per square inch and also the ratio of weld to solid is concerned, but as regards the contraction of area and the extension, those results are the mean of the welds which broke (of necessity, where the weld did not break, we could not obtain the contraction or give the ultimate extension).

DAVID KIRKALDY & SON,

99, Southwark Street, London, S.E.

July 18*th*, 1891.

Messrs. Lloyd & Lloyd,
Coombs Wood Tube Works,
Halesowen, near Birmingham.

TABLE No. II.

SUMMARY OF RESULTS OF EXPERIMENTS TO ASCERTAIN THE TENSILE STRENGTH, ETC., OF 10 BARS OF EACH OF THE UNDERMENTIONED SIZES AND BRANDS HAND WELDED BY SMITHS IN THE EMPLOYMENT OF A FIRM OF ENGINEERS, COMPILED FROM THE DETAILED REPORTS.

Size.	Brand.	Ultimate Strain Per Square Inch.	Contraction of Area at Fracture.	Extension in 10 Inches.	Ratio of Weld to Solid.	Figure of Merit. Ultimate Strain Multiplied by Contraction of Area at Fracture.
Inches.		Tons.				
2 × $\frac{3}{16}$	Low Moor ...	20·3	15·2	7·3	77·9	308
"	" ...	*21·1*	*17·3*	*7·3*	*81·1*	*365**
2 × $\frac{5}{16}$	" ...	21·5	22·3	11·3	90·7	479
"	" ...	*21·8*	*20·7*	*9·7*	*91·8*	*451**
2 × $\frac{1}{4}$	Netherton Best...	18·4	10·1	3·4	84·4	185
"	" "	*20·1*	*10·8*	*4·5*	*92·0*	*217**
2 × $\frac{1}{8}$	Parkgate Steel...	20·9	9·3	1·9	69·1	194
"	" "	*22·8*	*18·4*	*3·8*	*73·6*	*410**
2 × $\frac{1}{2}$	" "	20·4	15·9	8·1	82·3	324
"	" "	*21·0*	*15·4*	*7·3*	*86·4*	*323**
					118·5 per cent. =	$\frac{1,766^*}{1,490}$

* Electrically heated.

NOTE.—The figures in italics represent the results given in the preceding report, obtained by electrical heating, and are inserted for comparison only.

The mean of the electrically heated welds is therefore 18·5 per cent. better in "figure of merit" than the mean of the hand-made welds.

The welding of the (hand welded) iron bars has been very well done, the difference being slight compared to the same sizes electrically welded; but, coming to the steel, the hand is more irregular or uncertain, some being very good and others very bad.

DAVID KIRKALDY & SON,

99, Southwark Street, London, S.E.

July 25th, 1891.

In conclusion, the writer begs to point out that this process of electric arc welding is not proposed as a substitute in all cases for the ordinary methods of welding now in use, nor is it proposed as a substitute for riveting in the manufacture of high pressure boilers, but rather as an additional method, capable of very extensive application under conditions

where the ordinary methods of welding are inapplicable. The simplicity of the process, and the ease with which the working apparatus can be transported to the place required, combined with the nature of the work capable of being accomplished, as illustrated by the numerous examples given, are, in the writer's opinion, sufficient reasons for its more extended application; and the writer respectfully submits that it is difficult to conceive a more useful application of the process of electric arc welding than that which would be obtained from a small steam craft with the necessary welding plant and cables on board, and capable of plying up and down the river and effecting repairs of the nature of those illustrated, either in the works adjacent to the river while lying alongside a wharf, or on board a ship when moored close by.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

ELEVENTH SESSION, 1894–95.

PROCEEDINGS.

SIXTH GENERAL MEETING OF THE SESSION, HELD IN THE LECTURE HALL OF THE SUBSCRIPTION LITERARY SOCIETY, SUNDERLAND, ON TUESDAY EVENING, MARCH 12TH, 1895.

ALDERMAN THOMAS RICHARDSON, B.A., J.P., PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, held in Newcastle-upon-Tyne, on February 12th, 1895, which were approved by the members present, and signed by the President.

The ballot for new members having been taken, the President appointed Messrs. H. Macoll and Wm. C. Mountain to examine the voting papers, and the following gentlemen were declared elected :—

MEMBER.

Wood, Joseph, Foundry Manager, Deptford Yard Brass Works, Sunderland.

ASSOCIATE.

Bingham, J. E., Col., Manufacturer, West Lea, Sheffield.

GRADUATE.

Macdonald, William, Engineer, 15, Union Street, Hartlepool.

Mr. W. C. MOUNTAIN replied to the discussion on his paper on "Transmission of Power by Electricity."

The discussion on Mr. Henry Forster's paper "On the Application of the Electric Arc to Machinery and Boiler Repairs, etc.," was opened and adjourned.

Mr. S. O. KENDALL read a paper on "Turret-deck Cargo Steamers."

ADJOURNED DISCUSSION ON MR. W. C. MOUNTAIN'S PAPER ON "TRANSMISSION OF POWER BY ELECTRICITY."

The PRESIDENT said he had to express his regret for not being present at the last General Meeting, and so having unavoidably missed the discussion that took place upon Mr. Mountain's paper. He would like to take that opportunity of complimenting him upon its excellence, and also to thank him personally for the very kind reference he made to his presidential address. There was only one thing he took exception to, and that was the remarkable way in which he charged him with having cut the ground from under him. He (the President) thought he had certainly opened the ground, if not paved the way for him, so it was a very great disappointment that instead of being complimented upon doing him a good turn he actually charged him with doing the reverse. He did not need now to go into the paper, but would just like to say that it occurred to him there were a great many manufacturers in this district who were convinced that by the adoption of electrical driving under certain conditions there would be a considerable saving. They were all pretty much in the same position just now, necessarily very eager to avail themselves of anything that would reduce the cost of production, and that whilst some had made a start, the majority might well be excused if in the present depressed state of trade they hesitated to expend money, however beneficial the result might promise to be. He thought Mr. Mountain's paper was a very valuable and instructive one, and when the time came, as they went on with electrical driving, they would be able to gain a good deal of instruction from the information which he had given them, for there was no doubt that as they severally decided to adopt electrical driving it was most important that the plant should be the most efficient possible, for none could afford to spend money experimentally.

MR. MOUNTAIN'S REPLY.

Mr. W. C. MOUNTAIN, in replying to the discussion, stated that he regretted very much there had not been more criticism upon the relative cost of the steam power system of transmission and the electric system, because it rested entirely upon the relative efficiencies of the two systems whether electric transmission would be largely adopted or not in the

future. Mr. Boyd in his remarks really put the whole matter in a nut-shell when he stated that the electric motor was an economical machine for utilising electrical energy, or in other words it was a machine which transformed electrical energy into mechanical energy with a very high degree of efficiency. It was a difficult matter to hit upon an ideal scheme which would commend itself equally to advocates of steam driving and advocates of electrical driving, because the two systems dovetail so closely into each other that a point very soon arrived when it was very difficult to decide which of the two systems was likely to be most economical. The writer's reason for deciding to compare the cost of a steam engine plant where there were ten small steam engines of 25 horse-power and an electrical plant with ten small motors of 25 horse-power was, because it was well within the knowledge of most engineers who were laying down modern works, that it was usually considered an extremely economical arrangement to have a small engine at the end of each line of shafting. In many of the Scotch locomotive shops, and also large marine engineering shops, this system of driving was very common, and therefore the writer considered that a comparison between what was generally supposed to be a modern system of engine driving would be a very fair comparison to place alongside electrical transmission. Thinking that possibly his figures respecting the economy of high-class compound condensing engines of modern power might be contradicted, the writer had some correspondence with Messrs. Hick, Hargreaves, & Co., of Bolton; Messrs. Musgrave & Sons, of Bolton; and Messrs. Robey & Co., Lincoln. Messrs. Hick, Hargreaves, & Co. very kindly took the matter up, and the following was their statement respecting the economy of their engines under varying loads and steam pressures:—"From our horizontal condensing engines, both cylinders being fitted with Corliss gear sufficiently jacketed, we should expect, from our experience, the undernoted results in actual daily working. The engines are assumed to be working under a fairly full, but not excessive load, and to be in good condition as regards the tightness of the valves and pistons. Boiler pressure, 100, 120, 140, 160 lbs. per square inch. Steam per indicated horse-power, 15·5, 14·5, 14, 13·5 lbs. As regards the consumption at one-half to two-thirds full load, we have not much reliable information, but you would not be far out if you take the consumption per indicated horse-power at half and full load as alike, and at two-thirds load as rather less than this, bearing in mind that when working at light loads you have to make a greater allowance to cover the friction of the engine." Messrs. Musgrave & Sons, of Bolton, also sent some figures by which

they showed that a Macnaughten compound beam engine working at their Atlas mills, with a high pressure cylinder 32 inches diameter by 48 inches stroke, and a low pressure cylinder, 48 inches diameter by 7 feet stroke, running at 30 revolutions per minute, with a boiler pressure of 120 lbs. per square inch, was consuming 13½ lbs. of coal per indicated horse-power per hour. Messrs. Robey & Co., of Lincoln, who were also makers of high-class horizontal engines with trip expansion gear, stated that they would have no hesitation in guaranteeing a consumption not exceeding 15 lbs., with one of their engines developing 400 indicated horse-power, and working with a steam pressure of not less than 120 lbs. per square inch with a condenser. They further stated that they considered that at three-quarter's load the consumption would be about 18 lbs., and at half load 20 lbs. A few days since the writer was in Manchester, and he was able to obtain the actual consumption of one of Messrs. Hick, Hargreaves, & Co.'s engines working in a Lancashire mill. This was not a trial test, but the result of daily working. The engine in question was a compound horizontal condensing engine fitted with Corliss valve gear, with high pressure cylinder 26 inches diameter, low-pressure cylinder 46 inches diameter by 60 inches stroke. The engine was designed to give 600 indicated horse-power, but was working to only 400 indicated horse-power. When developing this power the total consumption of steam, including the steam used for working the feed pumps, was 15·18 lbs. per indicated horse-power per hour. The evaporative efficiency of the boiler was 7·61 lbs. of water per lb. of coal, therefore the consumption of coal per indicated horse-power was 1·98 lbs. This very clearly bore out the writer's estimate as to the consumption of coal per indicated horse-power, and went a long way to prove the accuracy of the statement as to the cost of the steam engine plant. It would be absurd to suppose for a single moment that there could be any possible economy in putting down a dynamo either coupled direct to a steam engine or driven by belts or ropes, and to first of all turn the power into electricity, and then put a number of motors at points where line shafting could be driven direct by ropes from the fly-wheel of the engine and anticipate any economy; in fact, even assuming that there might be a loss of 10 per cent. due to the friction of the ropes it meant that, assuming the dynamo gave an efficiency of 90 per cent., and the motors an efficiency of 85 per cent., that they would be 15 per cent. worse off by adopting the electrical scheme, yet this was a practice which was being preached by some electrical engineers at the present time. Mr. Newitt, in his remarks, very wisely touched upon this point, and the

writer was extremely glad when he heard criticisms of this kind; at same time he had not, from his own experience, come in contact very much shafting which was in the perfect condition described Mr. Newitt. Having stated that an electric motor was extrem economical, in fact the most economical method of transformi electrical energy into mechanical energy, it became necessary in conside ing any system of electrical transmission to ascertain whether the lo in producing electricity in the dynamo, transmitting it through th cables, and transforming it into electrical energy, was less than b driving direct by ropes or belts, or of carrying steam through lon lengths of steam pipes to engines at various parts of the work Electrical engineers, who at any rate understood their business, did no claim that there was anything about the electric motor which mu result in economy by using it, but they did state, and they had eve right in doing so, that it enabled a high-class steam engine to be used a central point and the full benefit of this high-class engine to be utilis at distant points about the works with a far greater degree of economy most cases than could possibly be attained by using a number of sm engines or long lines of shafting. In making this statement the wr wished the members to understand that he had got past the stage wh it was possible to drive from a very economical engine on to the ma shafting. Every member knew that in an engineering works, exce such works as Messrs. Sir W. G. Armstrong, Mitchell, & Co.'s, with whi Mr. Newitt was connected as electrical engineer, the amount of pow required in each shop, or at any rate on each line of shafting, did not as rule exceed from 25 to 50 horse-power, and it was a well-known fact tha it was impossible to build a 25 or 50 horse-power steam engine with a single cylinder and non-condensing, and also arranged to take its steam from a long length of pipe, to compare in any way with the compound horizontal condensing engine of large power, *i.e.*, the whole of the power being grouped into one engine. The writer expected some criticism on the steam consumption which he gave, viz., 68 lbs. per effective horse-power in the small engines of 25 horse-power each, which he described as distributed throughout the works, but he thought that the figures given in the paper were conclusive as to the correctness, generally speaking, of this consumption of steam, and therefore he, without any hesitation, confirmed the figures already given, viz., that an effective horse-power could be produced for approximately £5 per annum by electricity, against a cost of £10 per annum with a number of small engines scattered over a works. The writer thanked Mr. Tweddell for his state-

ment that he considered the elementary information given in the paper of value to mechanical engineers. The paper was not written with the intention of being in any way dedicated to a body of electrical engineers, but the writer's object was to endeavour to put before mechanical engineers and those occupied in manufacturing businesses, who might at the present or some future date contemplate the adoption of electrical transmission of power machinery in their works, the system upon which such plants were designed, and he ventured to hope and also thought that the information contained in the paper would be of value, as certainly an ordinary transmission of power scheme could be satisfactorily laid down if the lines indicated by the paper were closely followed. Mr. Tweddell, in his opening remarks, immediately started away with the assumption that there was something wonderful about an electric motor, but the writer thought that the statements he had already made would clear Mr. Tweddell's mind on this point, as, after all, an electric motor was only economical when suitably applied. If Mr. Tweddell was thinking of laying down a hydraulic system throughout a works, were it to be used for working hydraulic cranes or for riveting machinery, he would unquestionably concentrate the whole of his power into one large set of pumping machinery, and he would also make these engines as economical as he possibly could; and the writer ventured to think that it was rather unfair of Mr. Tweddell to suggest that an electrical engineer, in laying down a transmission of power plant should not insist upon equal advantages, and he was also quite sure that if an electrical transmission of power plant for driving cranes or other machinery throughout a works could be laid down to compete against a hydraulic scheme that the ultimate economy would be in favour of the electrical scheme, although there was no doubt that hydraulic power had many advantages in some directions not possessed by electricity, but on the other hand the electrical system had corresponding advantages in other positions. Mr. Tweddell rather objected to the table given in the paper, in which the resistances were given per mile of conductor. The writer would remind Mr. Tweddell that in dealing with electric transmission it was rather the miles that the electrician courted in preference to the yards, because when it came to yards there was not much chance of superseding steam power, but when it came to a question of miles the steam power had no chance at all; however, he was glad to have the opportunity of giving the information which Mr. Tweddell required as to the cost of conductors per yard, so that he might compare the cost with iron or copper pipes per yard for the hydraulic system, for which

bent appeared to criticise the writer's paper rather fr a
ıdpoint than a practical one. As the writer had al ly
ıd oured to put the electrical units into a sim f m,
e them as far as he possibly could with the ter sed b by
engineers, viz., pressure, quantity, and foot-poı s, an nd
ɔly it might be difficult to do this without giving an ı nalog gy,
Broadbent appeared to object to, the writer could unhe si-
ɾ that if the units as explained and applied by him w re
rs need not fear the results. Without wishing to critic ise
lbent's remarks in anything but a friendly manner, the wri ter
.e to state at the outset that he considered the members pres nt
ɜe capable of looking at the subject from an intelli ent poı int
and it was therefore not necessary to spend a great length o of
ɜxplaining the electrical units, nor did he consider it necessa ry
ın to them what became of the electricity when it ɾas utilised sed
lectric motor, and he further ventured to think that the diagram am
on the blackboard would not help very much to elucidate this. his
ıg, however, Mr. Broadbent's remarks on m ıical design, n,
iter could not help flatly contradicting Mr. nt as to his his
ıent that solid bearings were a good job. Any m ıical engineer, er,
any rate, any engineer who undertook to turn o fi ɪt-class work, rk,
l never dream of making main b ings or quick running ing
ings solid without any means of adjı , b , however wel ell
machinery was balanced, wear and m ta ɔlace in time ;
., further, assuming that by any chance the b ing was allowed to
dry and heat and the shaft became cut, it would be almost an
ɔossibility to get the bearing off the shaft; in fact, the writer had
ı many cases where solid bearings were used and had seized, when
ıad been necessary to cut them in pieces off the shaft. Considering
the advisability of placing the magnets over the armature and also
ıding the magnet coils in separate bobbins, the writer was also bound
in to express his entire disagreement with Mr. Broadbent's state-
ıts. To wind bobbins direct on to a field magnet core was nothing
a shoddy and cheap way of doing the work, and no firm pretending
turn out good work would for a single moment dream of building
ir dynamos in this way, however small they might be. The writer
very pleased that Mr. Newitt, who undoubtedly had had con-
ɜrable experience of running dynamos in difficult positions, *i.e.*, on
rd ship, so fully corroborated his statement respecting the advisability
ɔlacing the magnets over the armature to prevent oil getting upon

them. In the writer's own experience the bulk of the breakdowns of electrical machinery on board ship, and also in many land installations, was entirely due to the dynamo attendants allowing oil to run over the bedplate of the machine and on to the magnets. Mr. Broadbent referred to Kelvin's law, and it would perhaps have been advisable for Mr. Broadbent to have explained more fully what Kelvin's law was than to have simply skipped it over. Lord Kelvin stated "that the most economical area of conductor would be that for which the annual interest on capital outlay equalled the annual cost of energy wasted." If Mr. Broadbent had shown how the area was to be calculated from the above law and applied to actual everyday work, he would have been conferring a great benefit on the members present, but he either could or would not do so, and it might perhaps be of service to give the following extract from Mr. Kapp's work on electrical transmission, which at once shows how impossible it is to apply this law in practical work :—"Let us now see how the result can be practically applied. That the deduction here arrived at is not directly applicable to a transmission plant is obvious, because certain important premises have been disregarded. To see clearly that the law of maximum economy indiscriminately applied may lead to a wrong conclusion, we need only remember that, according to this law, the sectional area of the conductor is proportional to the current, and does not depend on the voltage of the generator or the distance of transmission. If the law as above enunciated were universally applicable, it would also have to fit a case where the voltage is low and the distance great, and under such circumstances it is quite conceivable that the whole of the available voltage is required for overcoming the ohmic resistance of the line, and that no power at all is delivered at the motor end. The law would thus seem to indicate that the most economical method of working a line of transmission is one under which we get no return at the motor end for our annual outlay at the generator end, which is obviously absurd. The fallacy does not, however, lie in the law, but in our application of it. The law itself is perfectly true. It says that if a certain current has to be sent through a given circuit, then there is one particular area of cross section for which the annual outlay of sending the current round becomes a minimum. The fallacy lies in this, that we assume the earning power at the motor end of the circuit to become a maximum when the cost of sending the current through the circuit becomes a minimum. This is not the case. The law also assumes that the power has the same money value all along the line. This can obviously not be the case, for if the annual horse-power could be pro-

duced locally, at the motor end as cheaply as it can be produced at the generator end, then there would be no need at all for a transmission plant. Further, the law assumes that the electrical horse-power has a certain annual value quite irrespective of the voltage at which the current is delivered. This, again, is not correct. Generators for a very high voltage cost more to build and maintain than generators for a moderate voltage. It is thus obvious that the voltage at which the plant is intended to be worked must be taken into account in designing the line for the greatest economy. We must further take into account not only the interest and depreciation of the line, but also the interest and depreciation of the machinery at either end. The whole problem is exceedingly complicated, and cannot be solved by reference to the line only, the investigation must extend over the whole of the plant." The same gentleman also questioned the statement that a shunt motor would run at a practically constant speed under all conditions of load. If he had listened to or read the paper, he would at once have seen the calculation that was given respecting the loss of voltage in a length of cable, and this statement was only intended to apply to positions where the pressure was constant. Any electrical engineer designing a plant, and wishing to get a constant speed, would not fail to so design his dynamo that a constant pressure, or at any rate nearly constant, was given at the terminals of the motor. Mr. Broadbent's further remarks respecting the efficiencies of steam engines of large and small size were practically answered, so that it was not necessary to deal with this any further. The writer regretted that he did not state more clearly in his paper that it was not necessary to use highly insulated cables to carry current overhead, *i.e.*, aerially, but he quite thought that the members would recognise this without any definite statements. It was, of course, unnecessary to use highly insulated cables for any ordinary voltages if the cables were carried upon insulators for overhead work. Bare copper could be used in most cases, but it was sometimes advisable to have the cables taped and braided; and, therefore, in giving the cost per yard of various cables, the price of this class of cable was given. Several gentlemen had asked how the saving between the old system of steam engine driving, and the present system of driving by electric motors in the writer's works was arrived at. As he had explained, the original plant consisted of a Cornish boiler, a semi-portable boiler, and a vertical boiler, together with a separate steam engine for driving the erecting shop, machine shop, and pattern shop. The engines were all of an uneconomical type, and the boilers were also uneconomical, being worked at a low steam pressure. The new plant

consists of high pressure locomotive boilers for 160 lbs. pressure and an economical compound engine. The saving might be calculated as under :—Original consumption of coal per week, say, 25 to 30 tons, whereas the present consumption is about 12 tons, or showing, say, 15 tons per week. This means :—

	£
780 tons per annum, at 10s. per ton	390
2 men less are required to look after the machinery and engines, at £75 per annum each	150
Further, a shop 75 feet long by 45 feet wide is now available, and this alone, even for ground rent only, means a further sum of	150
Total	£690

In addition to this, however, as he had explained, the works had been considerably increased in size, so that the saving was actually more than the amount shown above. This was an example of what might be done in a large number of engineering works, and also in shipyards and collieries on the North-East Coast. In reply to Mr. Parshall, the writer was extremely glad that he took the very common-sense view of the remarks made by Mr. Broadbent on criticising the analogies; but referring to the efficiency of electric motors, particularly for tramcar work, the writer would remind Mr. Parshall that the ordinary method at the present time was to have no gearing at all, but to put the armature direct on to the axle, and to run the motor at a slow speed. This system had been very successfully adopted at Liverpool, and also on the London underground railway. There was no difficulty in constructing electric motors to run almost at any speed, but it simply became a question of cost, and one had to decide whether they should pay a little more and have a large motor, or whether they should adopt reduction gear and put in a motor costing much less money, and put up with a little loss. The writer gave some reliable figures respecting the loss in worm gearing in the discussion on the paper by Mr. Newitt, and he would refer Mr. Parshall to the figures then given. It was very satisfactory to note that Mr. Parshall so thoroughly bore out the economy to be obtained by substituting the electrical method of driving in place of the steam driving by small engines. At a large factory on the Continent, where the works were originally driven by steam engines having a total horse-power of 3,000, it was decided to put down transmission of power machinery and to drive the works from a waterfall about eight miles distant, and to put electric motors into the various shops instead of having steam engines distributed throughout the works, and instead of 3,000 horse-power being required, the works were now being driven with a little over 800 horse-power economically applied. Mr. Parshall mentioned the multi-phase system, and he was

ite right in predicting a considerable future for this system, but it was ily fair to point out that this system of driving had not been very much dopted in England up to the present time, because its economy only became apparent when it was necessary to convey the current over very long distances, and as they had not many waterfalls in England, and as a rule power had to be transmitted short distances, the continuous current system still held its own. The great objection to the multi-phase system was that the motors must run at a constant speed, and if they got out of phase the machines took an enormous amount of current and gave very little power. Further, these motors had the disadvantage that they absorbed a great deal more than the normal working current at starting, and, further, it was very doubtful if they had the same all-round economy as continuous motors. Mr. Parshall and Mr. Tweddell both raised some objection to the armatures of continuous current dynamos, and also the commutators, and the brush arrangements. The type of armature upon which their criticism was chiefly based, whilst representing the general type of armature used in small machines, could not be exactly referred to when large power schemes had to be considered, and there was no reason why even armatures constructed as the one exhibited should not and did run for many years without the slightest trouble of any kind. The writer regretted that he could not quite bear out what Mr. Parshall stated respecting the economy of the three-phase system as regarded the amount of copper consumed in the cables, but as this system was not under discussion he would not deal further with it. There was only one more point to touch upon, and that was the efficiency of motors of less load than the particular load for which they were designed, and the following table was given which contained the information asked for, *i.e.*, the speed efficiency at full load, and efficiency at half load:—

EFFICIENCIES OF MOTORS AT FULL LOAD AND HALF LOAD.

Horse-power.	Full Load.		Half Load.	
	Efficiency.	Watts per Horse-power required.	Efficiency.	Watts per Horse-power required.
	Per Cent.		Per Cent.	
50	90	829	84	886
40	88	848	81	915
25	85	878	77	965
15	80	904	72	1,035
5	75	995	65	1,148
3	70	1,066	60	1,244
1	65	1,148	54	1,380
½	60	1,244	49	1,520
¼	55	1,357	44	1,710
	50	1,492	40	1,865

It had already been explained, however, that motors could be designed for any speed for which they were required, and it merely became a question of price, therefore the consideration of speed need not enter very much into the arguments.

On the motion of the PRESIDENT a vote of thanks to Mr. Mountain was accorded by acclamation for his interesting paper.

NEWCASTLE-UPON-TYNE,
March 13th, 1895.

DEAR MR. DUCKITT,

I intended to make some remarks at the adjourned discussion on Mr. Mountain's paper yesterday, but unfortunately arrived at the meeting too late to do so. I should like, however, if I am in order, to take advantage of Mr. Mountain's invitation to criticise the tables in which he compares steam and electric plants. We find from these tables that if an old-fashioned steam plant costs £4,800 an equivalent electric plant costs £5,000, but if you analyse this latter cost you will find that it includes a modern steam plant, capable of doing exactly the same work as the old-fashioned plant, but costing only £1,950, and to that is added a sum of no less than £3,050, making a total of £5,000, for the privilege of driving the shop electrically instead of by shafting. Again, if you look at the comparative tables of cost of working you will find that while the old-fashioned plant cost per annum £2,500 a steam plant on modern lines would cost something under £1,000 It seems to me that the savings which Mr. Mountain deduces are practically not due to the intervention of electricity at all. Further, managers of engine works and similar concerns know very well the proportion which the cost of motive power bears to total expenditure. Does the cost of the motive power amount to more than 2 per cent., or even 3 per cent., of the outlay in wages, charges, depreciation, etc.? I put this forward to show that, as a rule, you have not a great margin in which to effect economy, and that a marked increase in dividend does not necessarily follow the introduction of electromotive force into a factory. I do not wish to say anything against the merits of electric driving under certain conditions, but I think that the cases in which it can be applied with advantage are the exception and not the rule.

Yours faithfully,

M. SANDISON.

CLOSE WORKS, NEWCASTLE-UPON-TYNE,

DEAR MR. DUCKITT, *March 29th*, 1895.

I have received Mr. Sandison's letter, and I am sorry he had not an opportunity of joining in the discussion on my paper. Mr. Sandison appears to me to compare the steam plant and electrical plant described in my paper on an entirely wrong basis. My estimate of £4,800 for the steam power plant was not, as he seems to imagine, for an old-fashioned plant, but for a modern plant suitable for engineering works in which there are ten 25 horse-power engines scattered over the works, and fed from two Lancashire boilers; such plants can be found in a large number of modern engineering shops, and it is considered quite modern practice to adopt this system of driving, *i.e.*, a number of small engines coupled on to the various lines of shafting; I therefore thought this was a fair basis of comparison with electrical plant. Assuming, as Mr. Sandison states, that we analyse the cost of the steam power plant, it is quite true that the sum of £1,900 is included in the cost of the electrical plant as representing the value of the engine, boilers, and foundations, but Mr. Sandison appears to entirely overlook the fact that in addition to this sum it would be necessary to go to an enormous expense in shafting, belting, ropes, or other devices to enable the power of the engine to be distributed over the entire works as it is proposed to do with the electric motors. I think Mr. Sandison does not recognise the great cost and loss of power in transmitting power from one large steam engine to a number of shops over a large area, and he must entirely disabuse his mind that in making up the estimate I refer for a single moment to an old-fashioned plant. *Electricity enables the whole of the power required in the works to be centred in one large engine, which can be of the most economical type, and from the dynamo driven by this engine electricity can be led at a much less cost than by shafting, belting, or any other system to distant points, and at these points turned into power by means of an electric motor at a much cheaper rate than it is possible to do by distributed steam engines of small size, or by conveying the power from a large engine to the distant shops by shafting or belting.* As I explained in my reply, there can be no possible economy in adopting electric motors where a large and efficient engine can drive direct on to line shafting or on to its work, and electricity only becomes economical when this system is impossible and it is necessary to transmit power for long distances or to a number of points where it is impossible to drive direct. I am satisfied that in such positions an electrical plant can be put down at a

cost slightly exceeding a steam plant, but that it would save its whole expense in three or four years, which, at the present time, is a saving which cannot be disregarded by any firm wishing to economise in the cost of production.

Yours faithfully,

W. C. MOUNTAIN.

DISCUSSION ON MR. HENRY FOSTER'S PAPER "ON THE APPLICATION OF THE ELECTRIC ARC TO MACHINERY AND BOILER REPAIRS, ETC."

Mr. J. E. STODDART said they were much indebted to Mr. Foster for his instructive and interesting paper, but he must confess that he had given just enough information to make one desire a little more. The question arose, what about the local heating of steel plates of boilers when repaired without being removed? Table No. I., page 180, went to prove what was found in practice, that steel above 26 tons per square inch tensile strength was not so reliable at the weld as steel below 26 tons per square inch. It would be seen that in this table only one set of tests averaged more than 26 tons, so that if they took the ratio of weld to solid in the one set of samples above 26 tons they had 73·6 per cent. compared with 82·2 per cent., which was the mean ratio of the five sets of samples below 26 tons, and they had 89·2 per cent. mean ratio for iron. Now, he thought this point was worth remembering when they were about to weld steel, or iron with steel. In the above table the ratio of weld to solid was carefully pointed out, but what about the ratio of elongation in the welded and solid steel plates, for welded steel above 26 tons had a ratio of only 17 per cent. that of solid plate? The best sample of steel below 26 tons had a ratio of 23·1 per cent., whereas the worst sample of Low Moor iron had a ratio of 37·4, so that iron had an immense advantage over steel. They all knew that iron was not affected in the same manner as steel by local heating, he should therefore like to know how much of this fall in the percentage of elongation was due to local heating when welding by electricity, for he imagined the samples were not annealed after being welded. It would also be interesting to know whether a steel plate was affected in any way by passing a strong current through it. If the author of this valuable paper would kindly take, say, ten samples from a steel plate ½ inch thick, having a tensile strength of about 30 tons per square inch, and ten samples from a steel plate of about 26 tons per square inch tensile strength, both plates of the same thickness, then (not weld) but locally heat by electricity, five samples of each plate midway between the ends, and test the tensile strength and elongation of them, also test the five remaining samples of each plate in the usual way. A comparison could be made, and some light would be thrown on the

condition of steel when locally heated and on the effect of passing current through a steel plate. If a plate could be annealed in place electricity after being locally heated then the process of welding electricity would be invaluable where repairing a boiler was concern He hoped Mr. Foster might see his way to make the tests sugges before he replied to this discussion, so that his valuable paper might as complete as possible. He again thanked him for the information had already placed at their disposal.

Mr. W. C. MOUNTAIN heartily congratulated Mr. Foster upon paper on electric welding, because he said it was a paper which would of the very greatest value to the Institution and to the engineerin profession generally, as it contained so much valuable information pu into a thoroughly practical form. For some time he (Mr. Mountain was afraid that electric welding, or, in other words, electric melting by the arc, had more or less fallen into disgrace, and they had really not very far to look to discover the cause. Personally, he had from the commencement taken a very great interest in electric welding work having, he believed, built and designed the first dynamo used for this process, at any rate on a practical scale in England, these being the machines supplied to Messrs. Sir W. G. Armstrong, Mitchell, & Co., for the lighting of their steel works, and which were used for electric welding. The process was then taken up by Messrs. J. Spencer & Sons, Newburn, and the machines used by that firm he also designed, and since that date his firm had supplied some of the principal steel founders in England with plants in connection with this process. The reason Messrs. J. Spencer & Sons had been so successful with their work arose purely from the fact that they had had machines large enough for the work. There was no doubt that Messrs. Lloyd & Lloyd, of Birmingham, who acquired the Bernados patents, were principally to blame in the first instance by imposing such a heavy royalty for the use of the process, and steel founders and others wishing to adopt the process were compelled to put in as small a plant as possible, on account of the heavy royalty; but he was glad to know Messrs. Lloyd & Lloyd had reconsidered their terms, and they were now offering very much more favourable conditions. From his own experience he had found for welding, or, in other words, melting, up defects in steel castings, and also for repairing forgings, etc., that it was impossible to do good work with a current of less than 300 ampères, and to cope with whatever work might crop up in a steel foundry he considered that the dynamo should be capable of giving 500

ampères at the very least. This confirmed Mr. Foster's statement, and he was quite sure if dynamos of this size were used instead of the machines for 100 or 150 ampères, which were put down in some of the steelworks in Sheffield and elsewhere, that they would not hear of the defects in the heating which were so frequent. If a small machine giving a current of only, say, 150 ampères were used, it was impossible to get sufficient heating effect to more than just locally heat the spot where the current was applied, but having a larger current the heat was spread all round the defect, with the result that a solid weld or melt was obtained. A few days since he happened to be in Sheffield, and he saw an attempt being made at a works, to whom his firm had just supplied a welding plant, to weld up the defects in a stern frame with their old plant, which gave 100 ampères, and they might just as well have applied a match as attempted welding satisfactorily with the arc they obtained from the machine. He should be very glad if Mr. Foster would give him more information as to the tensile strength and elongation which he had been able to get from steel plates which he had welded by his process. He attempted some time since to weld up boiler flues prior to flanging and they had a great difficulty in getting the steel to stand the flanging, as it was apparently to some extent burnt, and it might possibly be of some interest to the members present if he gave a statement of some actual tests made upon welded wrought iron boilers for greenhouses and for domestic purposes. The object in conducting these tests was to be able to ascertain whether the process was likely to supersede hand welding, and the table would be interesting inasmuch as it gave pretty conclusively the length of steel which could be welded at a time, together with the time occupied in doing it. Result of tests made on June 11th, 1892, in welding two steel boilers; thickness of steel, $\frac{3}{8}$ inch:—

Volts at Battery.	Volts at Arc.	Current in Ampères.	Time of each Heat.	Length Heated in Inches.
			Minutes.	
130	—	370	2	2
115	—	400	$1\frac{1}{2}$	3
120	—	350	$1\frac{1}{2}$	3
115	—	350	$1\frac{1}{4}$	$2\frac{1}{2}$
113	75	350	$1\frac{1}{2}$	3
115	85	350	$1\frac{1}{2}$	3
118	65	250	$1\frac{3}{4}$	2
122	85	300	$1\frac{1}{4}$	2
122	85	350	$1\frac{1}{2}$	3
122	75	250	$1\frac{1}{2}$	last weld

Total length welded, 100 inches in 85 minutes, 1 inch in 51 seconds.

IRON $\frac{5}{16}$ THICK.

116 ... 75 ... 300 ... 45 seconds $2\frac{1}{2}$

tests proved pretty conclusively that to weld a steel plate [illegible] ate
ı thick required a current of not less than 300 to 350 ampères [illegible] es,
ı prior to the experiments being made it was considered that [illegible] a
nt of 100 ampères could be employed. He thought that some [illegible] me
nction should be made between what might be called electric melting [illegible] ing
electric welding. To melt, it was only necessary to have an electro [illegible] ro-
ive force of about 75 volts at the dynamo terminals, and of course [illegible] e a
nce must be placed in circuit to steady the arc; but to weld, that [illegible] at is
, to join together two pieces of rolled or hammered steel or iron [illegible] n it
s necessary to have an electro-motive force of 115 to 120 volts, and [illegible] to
ıve a very long arc, which could be used in the same way as a blow pi [illegible] ipe,
ıe arc being rapidly moved over the surface of the plate, so that it [illegible] was
ıot allowed to impinge for any length of time on one spot and melt [illegible] the
netal. He had found this to be necessary in connection with the pl [illegible] ant
which he supplied for electric welding of barrels, and the results had b [illegible] een
very satisfactory. From his own experience he could most unhesitatin [illegible] gly
te that if electric welding plants were made large enough, that is [illegible] to
, that the current per arc was not less than 350 to 400 ampère [illegible] es,
very excellent work could be done, as was shown by the samples produc [illegible] d in
by Mr. Foster, and also the tests made by Messrs. Lloyd & Lloyd, i [illegible] el
Birmingham, and there was no doubt that the defects welded up in stee [illegible] od
castings or in forgings repaired in this manner were a thoroughly good [illegible]
job; but it was nearly certain that when electrical plants were put down
too small for the work a proper adhesion was not obtained between the
casting and the piece of steel melted into it, and they then heard of the
bad work that had caused this process to be condemned to a great extent
by the Admiralty, etc. On referring to the diagram, Fig. 2, Plate XLV.,
he should be glad if Mr. Foster would explain his reason for inserting
so many small resistances in circuit. He had found it desirable to have
a separate resistance to each arc, and he hardly thought that the method
adopted, viz., placing the three arcs on one set of resistances was likely
to be satisfactory, because when one or more arcs were stopped it meant
upsetting the current passing through the remaining arc. He was
inclined to think that a resistance frame consisting of eight to ten coils,
with a switch arranged so that from one to ten of the resistances could
be put in circuit, was a much more convenient and satisfactory arrange-
ment than the one proposed, and also had the advantage that it was
more portable. He was very glad to note that Mr. Foster in designing
his plant decided to drive by belt on to the dynamo. Several attempts
had been made to use direct coupled plants, *i.e.*, the engine coupled

direct on to the dynamo, but owing to the tremendous shock that is thrown upon the engine at the moment the arc is struck such an arrangement, as far as he was aware, had always given more or less trouble, and in his opinion it was absolutely necessary to have some elastic medium, such as belts or ropes between the engine and dynamo.

Mr. L. Newitt said he would like to ask Mr. Foster a few questions with reference to electric welding. Some time ago he (Mr. Newittt) had seen descriptions given of an arrangement in which the electric arc could be directed by the aid of a powerful electro-magnet placed near to the flame. If this were true, the heat of the electric arc could be directed to any point where the heat was required, and consequently a new field would be opened up to an already extensive use of the arc for repairing castings and other work. Then, again, according to the paper and what Mr. Mountain had said, it was desirable to have a very long arc, extending in some cases up to 5 inches. He had made some experiments, and found by using aluminium cores in the carbons it was possible not only to get higher temperatures but also to get a longer arc than by using ordinary solid carbons. It had also the advantage of keeping the carbon from becoming too pointed, and therefore reducing the current below what would be required for the making of a successful weld. With reference to that part of the paper dealing with portable and convenient resistances, the one shown in diagram did not appear to meet all the points required of it unless extra labour was used for its adjustment. He (Mr. Newitt) would suggest one which appeared to have all the necessary qualifications, and one which could be manipulated by the foot of the man using the welding arc, consequently when he required more or less current the workman had only to raise or lower his foot, and by so doing raise or lower large plates of metal in a solution of dilute sulphuric acid and water. These plates would be connected up in the direct circuit, and according to the amount of immersion so could the quantity of current be regulated. It would be interesting to know if this form of resistance had been tried for this work. There was no doubt as to the utility and the great advantages derived from the use of the electric arc for welding purposes, but its adoption for the boring of holes in metal plates was doubtful. No doubt it was a very pretty experiment, but he (Mr. Newitt) would imagine that if the work was forced at all the machinery would be strained owing to the carbon coming in contact with metal being drilled; and then there was the question of expense. Taking a rough estimate of the price of work mentioned by Mr. Foster,

viz., 304 holes, each 1 inch diameter, through $\frac{5}{16}$ inch plate; current, 500 ampères; electro-motive force about 70 volts. 500 ampères by 70 volts gives 35,000 watts, which is 35 units. Now, for a small plant of this kind 6d. per unit per hour would not be considered too large, so that this plant cost 17s. 6d. per hour, and we are told that it was in the welding house seven hours, and the work was required in a hurry, so one may assume that the work was going on nearly all this time, therefore the above work would cost 17s. 6d. by 7 hours, or about £6. For comparison with ordinary hand-drillers this is not very favourable, as according to the piece prices paid for this class of work the same could be done for 19s. The loss of metal due to volatilization should also be taken into consideration. There was one other point he would like to raise with reference to using electricity in repairing the teeth of small cog-wheels. Would it require as much as 500 ampères for this work, and if water was used on the molten metal, and all corrosion immediately brushed off, was it found to increase the solidity and effectiveness of the work when done?

TURRET-DECK CARGO STEAMERS.

By S. O. KENDALL.

[Read before the Institution, in Sunderland, on March 12th, 1895.]

It is the object of the writer, in submitting to the members of this Institution the following notes on the "Turret-deck Cargo Steamer," to make an enquiry into, and promote a discussion on, the various merits or demerits of this class of vessel, in the hope that such an enquiry and discussion will not only prove useful in adding to our knowledge of the subject, but that it will be of general interest to the majority of members who are concerned in the development and improvement of our mercantile marine.

As a basis of discussion, the writer proposes to submit the results of a comparison which he has made between a turret vessel already built and two other cargo vessels of ordinary type.

The endeavour has been to make an impartial investigation into the technical merits of each type, in order to ascertain as near as possible the extent to which this latest type of cargo steamer may be said to meet the growing desire of shipowners for a freight carrier, which, while giving better results as to deadweight, may be more economical in working expenses, and whose cost of construction may be reduced to a minimum.

The origin and development of turret-decked vessels are now so well known that to describe them may seem almost superfluous, especially in this town, the birthplace of the type, but it may be interesting to those members who are not so intimately acquainted with the shipbuilding events of this district to briefly outline the career of what is now a recognised type and factor in the freight-carrying tonnage of the world.

The turret type of cargo steamer owes its origin to the invention and enterprise of the patentees, Messrs. W. Doxford & Sons, of the Pallion shipyard, whose energetic development of the type may be taken as a practical proof of the confidence they feel as to the ultimate success of the type when commercially pitted against the ordinary "tramper."

In the early days the turret vessel was frequently described as a "whale-back" steamer, or as an "improved whale-back," although as a matter of fact there is considerable difference between the two, as will be readily seen by reference to Plates LV. and LVII., the particulars of which will be mentioned later on.

The reason of this confusion is evidently to be found in the fact that attention of the mercantile marine community was first directed to possibility of getting better results from freight carriers by means of somewhat radical change from the existing types, by the visit of the ale-back steamer, "Chas. W. Wetmore," to this country in the autumn 1891. This vessel was radical enough to please the most revolutionary aste, and many owners waxed enthusiastically prophetic as to the future of this class of vessel as the freight carrier of the world.

These prognostications, however, have not as yet been fulfilled, nor does their fulfilment appear probable, for this, the first visit of the tramp of the American lakes across the Atlantic, has proved also to be the last, for after being nearly knocked to pieces on her voyage out round Cape Horn, she soon afterwards ran ashore, and became a total wreck.

The defects of the whale-back steamer for the purpose of ocean trading are obvious. In the first place, the difficulty in getting about the boat is very great, the navigating platform consisting, in some places, of a mere gangway formed by a couple of square derricks placed side by side. Secondly, there is nothing to act as a feeder when carrying cargo in bulk, the hatches being simply plates bolted to the deck without coamings, and consequently these hatches can only be made very small. Thirdly, from the form of the midship section (Fig. 3, Plate LVII.) the upper part of the vessel is not suited to withstand the compression of severe sagging strains, there being no stiff gunwale or its equivalent, and the spoon-shaped bow is not suited for meeting a heavy head sea on account of the excessive panting strains to which it is subjected in falling on the breast of a wave, and also in the difficulty of steering a course in consequence of the fore-foot being cut away.

On the other hand there is considerable saving effected in the cost of construction and in the reduction of tonnage, through the absence of sheer, and the simplicity of the rigging, etc., and there is no doubt that the type is well enough suited for the American lakes or a coasting trade.

In the endeavour to design a cargo vessel which would be free from the above-mentioned disadvantages, and which at the same time would have the economical construction of the whale-back, Messrs. Doxford, towards the end of 1891, evolved the type to which they have given the name of "turret," and early in the next year the first steamer of the new type, the S.S. "Turret," was laid down for Messrs. Petersen, Tate, & Co., of Newcastle, and it is a flattering commentary on the successful working of these steamers when it is stated that this firm have since increased their fleet of "turrets" to six steamers, having a total gross tonnage of 12,000 tons.

Naturally, the question of classification was a matter of vital importance to the new type, and although the design was accepted in principle by both the Bureau Veritas and Lloyd's, the latter society qualified their approval by the comprehensive proviso "with a suitable load-line," maintaining that the peculiar form of the vessels, the rounded gunwale, absence of sheer, and the central position of the buoyancy in the turret erection, necessitated the assignment of such a freeboard as would have effectually neutralized any advantages which might be claimed for the type. This point was really the crux of the whole question, and formed the subject of an animated discussion on the reading of Mr. F. C. Goodall's paper on "Whale-back Steamers," before the Institution of Naval Architects, in April, 1892. At that meeting exception was taken to the rounded gunwale, which, it was contended, would induce the waves to come up and overwhelm the deck, much in the same way as in the old flush spar-deck vessels with open bulwarks, where the water swept across the deck and over the lee side. The writer will refer again to this point, and it is merely mentioned to show the apprehension with which the unprotected "harbour"-deck at the sides of the turret and the rounded gunwale was viewed by many experts. Indeed one expert, writing two days after the departure of the S.S. "Turret" on her maiden voyage, in February, 1893, prophesied that she would not survive three seas, if caught broadside on, giving as a reason, "her being so wall-sided," and he then proceeded with confidence to prove his point minutely, as follows:—"She will never obey the call of the first sea in time to ease herself down into the volume of water contained in the second sea, but lurch right over into the trough, when, before she can recover herself, that sea will roll right over her, and with the weight of water around her she will never clear herself before the third sea will carry her down, if, indeed, she does not turn turtle at the second sea."

It is needless to say these alarming predictions were not fulfilled, and as though to refute them, although unaware of their publication, Captain Petersen, of Messrs. Petersen, Tate, & Co., who was in command for this voyage, on meeting with exceptionally heavy weather, voluntarily submitted the vessel to this very test, by placing her in the trough of the sea, when the maximum angle of heel was only 30 degs. each side of the centre, and the motion was described as being exceptionally easy.

After the satisfactory performance of the pioneer vessel, others were soon proceeded with, and up to the present time there have been built, or are now building for various owners, 14 steamers of this type having a total gross tonnage of 29,641 tons. (For the list of these vessels see

6th. By providing a high navigating platform it is possible to dispense with sheer and still retain the necessary reserve buoyancy, thus greatly simplifying the construction and at the same time reducing the tonnage to a minimum.

7th. By increasing the depth of the girder greater efficiency is obtained for resisting longitudinal strains, while at the same time the curvature of the gunwale and turret sides does not render this additional depth a source of weakness to the transverse strength.

8th. In the turret erection every part of the structure is utilised in the strength of the vessel, in addition to forming a navigating platform, so that by this means there is a considerable saving in weight, which increases the relative deadweight over that of an ordinary vessel, where it is usual to have a bridge or other erection on the deck for the accommodation of the crew. This erection not only does not add to the strength of the vessel, but often requires additional strength at the ends, and at the same time adds to the tonnage.

We will now proceed to examine the merits of these various claims, by aid of the comparison previously mentioned, and also the extent to which the turret-deck type fulfils the requirements of a vessel intended solely for the purpose of carrying cargo of varying density and character. The principal requirements of such a vessel may be summarised as follows :—

Maximum strength of construction.
" deadweight.
" cargo capacity.
" reserve buoyancy.
" freeboard to navigating platform.
" range of stability.
" speed.
" coal capacity.
" size of hatches.

And on the other hand :—

Minimum displacement.
" dimensions.
" net registered tonnage.
" draught.
" indicated horse-power.
" coal consumption.
" cost of construction.
" cost of working.

upper-deck stringer of the single-deck vessel, when subject to similar bending moments, viz., 7·249 tons against 8 tons. The reason of this of course is the increased depth of girder which is obtained with the turret erection in addition to the extra 7 inches of depth which is necessary in the turret vessel for freeboard on account of the absence of sheer; from which it appears that the turret vessels obtain additional strength through concentrating the material in the centre of the vessel and taking it from the ends. If, however, this were done in an ordinary vessel by taking away the sheer, the result would be an unseaworthy ship, but in the turret it is maintained the high platform obviates this defect.

As a general rule a reduction would also be obtained in the bending moment of the turret vessel when subject to hogging strains, through the vessel not being so heavily weighted with cargo at the ends; but in carrying heavy deadweight cargoes this advantage would disappear to a certain extent, so that the bending moment has been assumed to be the same in each case.

Again, in any structure subject to such longitudinal strains as those of an ocean-going vessel, if the depth of the girder can be increased without proportionately increasing the transverse strains to which it is subjected, then a distinct economy is effected in the structure, provided that the scantlings of the additional depth are sufficiently rigid to withstand the ordinary working strains without buckling, and this is a point which may be noticed with regard to the section of the turret vessel. If the side of the vessel were carried up with an ordinary "tumble home," to the level of the turret-deck, and the ordinary deck fitted there, it is very evident that this would necessitate a considerable increase in the transverse framing of the vessel by the introduction of beams, etc., to meet the increased strains on the extra flat of side; but in the turret vessel the curvature of the gunwale practically reduces the flat of side, and, combined with the round at the base of the turret, makes a section which does not add to the depth of unsupported side, and is evidently of a stronger form transversely than the long beam of slight curvature forming the deck in a vessel of ordinary type, while at the same time the above-mentioned reduction in the longitudinal strains is obtained, so that there is a net saving in the structure as a whole.

It may also be noticed that the turret erection also gives local strength in way of the hatches and openings in the turret-deck, forming a fore and aft girder, which effectually prevents any sagging of the deck in the way of the hatches, without any special pillaring, as in the case of an ordinary vessel, and in addition the whole of the pillars may be wide

ead of on every beam, by reason of the increased resistance o[illegible]ht to deflection; this effects a considerable saving in the weight [illegible]ill llars without diminishing the strength of the vessel. It wil[illegible]ter een that the strength of the turret vessel is somewhat greater [illegible]the at of an ordinary vessel of the same displacement, while at th[illegible] = of me the scantlings may in certain parts be reduced from those o[illegible] inary vessel.

ne importance of a saving in the weight will be readily appreciate[illegible]ted it is considered that every ton saved in the construction is a to[illegible]on ed in the deadweight earning power of the vessel, and also in t[illegible]the inished first cost to the owner, always supposing that the saving c[illegible]can effected without diminishing the efficiency of the structure.

Deadweight.—The turret vessel appears to be decidedly superior *to* oth the single-decked and part-awning-decked vessel as a deadwei[illegible]ht arrier. The latter type has generally been considered as the larg[illegible]est deadweight carrier on a given draught and displacement of any type [illegible]et designed, but on comparison it is found to carry about 4 per cent. l[illegible]ss cargo than the turret vessel, while the single-decked vessel carries 4·3 p[illegible]er cent. less.

The chief elements of economy appear to be in the saving in th[illegible] scantlings, through the favourable form of section, and in the beam[illegible] pillars, and in addition there is the economy previously mentioned, in [illegible] which the navigation platform is maintained and the longitudinal strength [illegible] is increased by the same structure; this is especially noticeable in the [illegible] comparison with the single-decked steamer, and, again, the bulwarks are [illegible] always open rails and consequently much lighter than the close bulwarks [illegible] in the single-decked vessel and in the after part of the part-awning-decked vessel.

It appears that, whereas the total deadweight of the single-decke[illegible] steamer is 69·6 per cent. of the displacement, and that of the part-awning-deck steamer 69·8 per cent., the proportion in the turret steamer is 72·5 per cent., an increase of 2·9 per cent. and 2·7 per cent. respectively on the total deadweight.

Tonnage.—If a large deadweight is a thing to be desired in the cargo steamer, a small registered net tonnage is equally desirable as a means of reducing the working expenses to a minimum, and here again the com parison is favourable to the turret, for the net register is 8 per cent. le than that of the single-deck steamer, and over 12½ per cent. less than t part-awning-deck steamer; indeed this latter type does not pretend t small net register, for by filling in the forward part this is sacrifice the freeboard and deadweight.

It will be noticed that the tonnage of the erections in the single-decked steamer are somewhat the same as those of the turret steamer, being 229 tons and 234 tons respectively, but, owing to the absence of sheer, the under-deck tonnage of the latter is much smaller than that of the single-deck steamer, and it naturally follows that the net register is also smaller.

Cargo Capacity.—The turret-decked steamer is essentially a deadweight carrier; in fact it is practically impossible to have a large measurement capacity and a small net register at the same time, since the latter is intended as a measure of the hold capacity, so that in this respect the turret is inferior to the part-awning-deck steamer.

The deadweight of case cargo fills the holds of the turret at 48·7 cubic feet per ton, as against 55·3 for the part-awning-deck vessel, but this apparent advantage in the latter vessel is discounted by the fact that these vessels cannot fill all the available space in the forward 'tween decks on account of the trim, and usually run with part of this space empty.

In this connection it is curious to notice the transformation which has been executed in the development of the part-awning-deck type from its prototype, the raised quarter-deck steamer. The *raison d'être* of this latter type was to secure an equal distribution of the cargo in each hold to compensate for the loss of space caused by the shaft tunnel, etc., and to ensure the vessel's trim by the stern, especially when carrying coal or other bulk cargoes, and after passing through various stages, we finally arrive at the exact reverse of the initial design.

A fairer comparison as regards capacity may be made with the single-decked vessel. In this case the holds are filled at 50·2 cubic feet per ton, as against 48·7 for the turret, but the actual measurement of the two vessels is almost identical, being 170,040 for the turret and 167,559 for the single-decked vessel.

The question naturally arises, how is it that the turret has less tonnage measurement and greater cargo measurement than an ordinary type of vessel? This apparent anomaly is explained by the different character of the erections. As before mentioned, the addition of the erections to the under-deck tonnage is about the same in both types, but whereas none of these erections are available for cargo purposes in the single-decked steamer (excepting the tonnage of hatches over ½ per cent. of gross tonnage), in the turret erection there is about 17,000 cubic feet of case cargo space available, which is more than sufficient to make up for the deficiency of the space below deck, and thus equalises the capacities, while

the difference between the tonnages maintains much the same ratio, as the difference between the tonnages under deck.

As regards the capacity for cargo in bulk, the turret vessel compares more favourably with the single-decked steamer, the latter having a measurement 2½ per cent. less than the former, the reason of this superiority for bulk cargo is to be found in the rounded base of the turret erection and the rounded gunwale. This allows of the bulk cargo trimming closer up to the deck than in the case of the ordinary decked vessel, where the space between the beams could hardly be considered as available for bulk cargo. The rate of stowage for bulk cargo in the turret vessel becomes 51·7 cubic feet per ton, so that as regards this kind of freight the type may be said to meet the requirements of most trades, but for case cargo there is no doubt that the vessel would be short of her proper load-line when carrying light case goods, timber, or cotton. In a vessel intended for the general cargo trade, however, it must be remembered that the best results would be obtained from a type having a medium capacity, so that the minimum of loss would be sustained in carrying cargoes of an exceptionally heavy or exceptionally light character.

In all three vessels the capacities for cargo include the reserve cross bunker over the donkey boiler shown in Plates LV. and LVI., Fig. 1. The permanent bunkers in all the types being abreast the engines and boilers, and hold about 275 tons in each case.

It would not be generally supposed that the harbour-deck at the sides of the turret was a suitable place for carrying deck cargoes, but the writer is informed that timber-deck loads are often carried here, and very satisfactory results are reported, and in no case has any loss been sustained, which seems to show that the space is more suitable than would appear at first sight. It is apparent, however, that any sea striking the deck cargo could not carry it over the lee-side on account of the turret erection, but the lashings would require to be very carefully made, or the cargo would roll off the deck. The principal objection is the stability, for it is essential that the turret-deck steamer should have a high initial G.M. at the load draught, which the loading up of a deck cargo would be apt to interfere with.

Stability.—Although the appearance of the turret vessel does not, as a rule, secure the confidence of the uninitiated as to its power to resist "turning turtle," investigation seems to point to the conclusion, which experience confirms that, if properly designed, there is no question as to the stability of the type, both as regards righting lever and range. This

will be seen by reference to Plate LIX., which shows the comparative curves of stability for the three vessels under consideration.

As before stated, the turret vessel requires a high initial G.M. at the load draught, for the rounded gunwale and absence of sheer and erections at the side would not otherwise give a sufficient righting moment at the smaller angles of keel. This, however, is mainly a question of dimensions, and in the case in question the G.M. is 2·75 feet when loaded with homogeneous cargo. For purposes of comparison a similar metacentric height has been taken in the other vessels. It will be seen from the curves that the feature of the stability of the turret type at load draught is a long range and a medium righting lever. The maximum of ·75 of a foot is reached at 23 degs. heel, from whence to 31 degs. there is a slight diminution of the righting lever to ·68 of a foot, at which point the turret comes into play, and the lever increases to a second maximum of 1·02 feet at 61 degs., and finally vanishes at 100 degs. The maximum righting arm of the single-deck and part-awning-deck vessels is much greater, being 1·7 feet at 48 degs. and 2·41 feet at 53 degs. respectively, but the range is slightly less than the turret vessel, viz., 92 degs. and 99 degs. It may be advanced that the righting lever of the turret is too small to give a reserve of stability in case of emergency, as in a sudden squall; but in this case there are no masts or top hamper to affect the vessel under these conditions, as in the case of a sailing vessel or heavily rigged steamer, so that although the motion will be easy it will be quite safe, and the reports of the sea experience of these vessels tends to confirm this conclusion, the motions being stated to be very steady and free from the jerky, uneasy action which prevails when the vessel is very stiff, as in the case of the two vessels whose curves of stability are shown in Plate LIX. If these vessels were steaming with an initial G.M. of 1·5 feet, loaded with homogeneous cargo, which is about what a well-proportioned vessel would work out at, the three curves, as shown by the dotted lines (Plate LIX.), would be found to be very much the same, excepting for the long range of the turret vessel.

The additional safety which the turret has, when loaded with homogeneous cargo in bulk, will be at once apparent; in fact, the efficiency of the turret erection as a grain feeder, and the slight effect of any movement of cargo in this erection as compared with the effect of cargo moving at the gunwale of an ordinary vessel, is so obviously in favour of the turret that it need not be further alluded to. There is, however, one other point which affects the stability of the turret type favourably as compared with ordinary vessels, and that is there is no chance of water making its way

the deck, and acting as a deadweight in the lee scuppers, and, [illegible]d, ıgh perhaps only temporarily, impairing the stability of the vessel. [illegible]el. ;ea gets on the harbour-deck it must go off on the same side. This [illegible]his is also of vital importance to the vessel's seaworthiness.

Reserve Buoyancy and Freeboard.—The question of the amount of [illegible] of :rve buoyancy and freeboard which shall be required for the turret[illegible]ret ;e of vessel is really the most difficult of the lot to decide, and one[illegible]one ;on which the greatest difference of opinion might be expected; but[illegible]but though a suitable load-line might be assigned on the same genera[illegible]eral rinciples which govern the position of the load-line in ordinary vessel[illegible]els, ;till the type is so novel that the question is one which can only reall[illegible]ally be decided by the evidence of practical experience. The main point i[illegible] is: What is the value of the turret erection in giving surplus buoyancy [illegible] to the vessel or in rendering her seaworthy and safe to navigate? T[illegible] The answer to this question, derived from the two years' sea experience of [illegible] the type, seems to be decidedly in favour of the turret erection. For instan[illegible]ce, the vessels of Messrs. Petersen, Tate, & Co., have, up to the pres[illegible]nt, made 64 voyages, carrying over 227,000 tons dead-weight, during wh[illegible]ich time there is no record of the turret-deck having been swept by a gre[illegible]en sea or of any serious damage to the deck fittings, although they ha[illegible]ve frequently encountered very heavy gales, in some cases amounting [illegible] to hurricanes, which seems to show that the value of the turret erection fo[illegible]for freeboard was originally rather under-estimated than over-estimated, an[illegible]nd this impression is confirmed from the fact that whereas the first vesse[illegible]s had the seamen and firemen placed in the stern under the impression [illegible] that there would be difficulty in getting along the turret-deck in bad [illegible] weather, the later vessels have the crew berthed forward in the usual [illegible] way, as no such difficulty has been experienced; and according to the [illegible] reports of the behaviour of these vessels in heavy weather, it appears that although the seas sweep the harbour-deck, they do not, as at first antici-pated, come over the turret-deck, but readily clear from the vessel again, there being no spaces for the water to lodge, thus leaving the upper platform comparatively clear with the exception of spray, while the harbour-deck, from its solid construction and the absence of fittings likely to be damaged by the sea, is none the worse for its partial immer-sion. Doubtless, this immunity is due to the height of the turret-deck above the water, viz., 10 feet 3 inches, whilst the freeboard to the harbour-deck is 4 feet 8 inches against 4 feet $2\frac{1}{4}$ inches to upper deck in the single-decked vessel, and 8 feet $10\frac{3}{4}$ inches to awning-deck in the part-awning-decked vessel.

Now, although the requirements of freeboard are generally summed up as being surplus buoyancy and height of navigating platform, there are other points to be considered, and these are the position of the hatches, ventilators, companions, and all vulnerable openings, with reference to the load-line; for as the strength of a girder is its weakest section, so the safety of a vessel may be gauged by the weakest openings, meaning weak as regards position, and in this respect the turret is greatly superior to other types.

Referring to Plate LX., Figs. 1, 2, and 3, show the relative positions of the three vessels when inclined over to various angles. From this it will be seen that the hatches of the single-decked vessel touch the water at 30 degs., and those of the part-awning-decked vessel at 36 degs., while those of the turret do not enter the water until 47 degs. are reached.

Of course this condition does not hold good in a sea-way, but for comparison the illustration serves to show the relative safety of the hatches. As regards reserve buoyancy the turret has 2 per cent. less than the single-deck vessel and 5·7 per cent. less than the part-awning-decker, but still the percentage is about 3 per cent. in excess of that required by the freeboard tables for a flush-decked vessel. The freeboard of the turret type is regulated by the reserve buoyancy alone (with an allowance for the hood forward over the windlass, etc.), and in arriving at the correct load-line, the value of the turret, for the volume of its displacement which is available for surplus buoyancy has to be estimated. There is no doubt that for actual lifting power the volume of the turret would be more advantageously placed at the sides of the vessel; but, as the writer has pointed out, there are other things to be considered than mere lifting power, and when the solid nature of this turret erection is considered, and the manner in which the openings are protected, and the safe gangway secured for navigation, the writer is of opinion that at least 60 per cent. of this turret erection should be considered as available buoyancy for freeboard purposes, or, in other words, that the volume of the turret erection should be discounted 40 per cent. on account of its central position.

The above comparisons have been represented in graphic form by the diagram on Plate LXI., in which the various particulars of the part-awning-decked and single-decked vessels are expressed in terms of percentage ratios to the turret-decked steamer, which is represented by a straight line, the lines of the other vessels varying according to the percentage which the particulars bear to the corresponding ones of the turret.

On considering the general features of the turret vessel, there are two questions which present themselves as being awkward points in the

gn, the one is: How to get the boats over the side? and the other, ow to get the ashes from the boiler?

With regard to the former question a glance at the arrangment in Pl LXII. will show that this difficulty is overcome in a very simple and fa ory manner. This arrangement (the patent of Messrs. Doxford) con of davits formed of H iron, hinging on a pin at the foot, having a sheave in the head over which the falls pass from the boat to a block secured on the casing or deck house, from which they may be led to a winch. The boat chocks, as may be seen, are composed of a double plate bracket riveted to the face of the davit, the outer chock hinging on the pin at the keel of the boat and secured by a pin. See Fig. 2, Plate LXII.

The davits are secured to the upper bulwarks by means of a key, an all that is necessary to lower the boat is to knock out this key an the pin securing the boat chock; the weight of the boat then causes th davit to fall outwards until stopped by a guy rope, after which the bo lowers away in the ordinary manner until placed in the water. This i a very simple arrangement, and the process of getting a boat out should be considerably accelerated when compared with the ordinary method of revolving davits.

In getting rid of the ashes the arrangement shown in Plate LX I. is adopted; this is "See's patent ash ejector," for the sketch of whi ch the writer is indebted to Mr. F. J. Trewent, the sole licensee of th he patent. This apparatus turns what would be otherwise a difficulty in th is turret vessel into an actual gain, for by this simple gear much labour he saved in the stokehold. The apparatus consists of a hopper placed in th At stokehold a little above the floor, and fitted with a water-tight cover. A ed the bottom of the hopper a V pipe is fitted, one leg of which is carried up and through the ship's side above the water-line; at the bottom of the V a valve and connection is made with one of the engine room pumps. To discharge the ashes the pump is first started, and then the valve is suddenly opened, and the water rushes up the pipe and out of the sides with considerable force. All that now remains is to shovel the ashes into the hopper, and they are drawn into the pipe by suction and discharged about 20 feet from the ship's side, mixed with the water, and therefore free from dust.

It has been the endeavour of the writer to carry out the comparison in as fair and accurate a manner as possible and without prejudice to either type, yet, while by no means looking upon the turret as a perfect type, or even as preferable for certain trades, there is, in the writer's opinion, no denying the fact that a decided superiority is manifested in

the type when intended for general cargo purposes of a deadweight character; and a glance at the comparison between the three types will show that, in its own particular line, the turret type would be earning a very fair profit on freights which would be hardly remunerative to the ordinary type of steamer.

It has been said that the result of developments such as this only increases the competition already so severe by making it more difficult for the older class of vessels to be profitably worked, but, in the writer's opinion, this argument takes a very narrow view of the subject, and is no more likely to deter the adoption of an improvement than it would have deterred the change from iron to steel as a shipbuilding material, or the step from compound engines to triple expansion.

TABLE A.

COMPARATIVE TABLE OF PARTICULARS.
TURRET-DECKED, SINGLE-DECKED, AND PART-AWNING-DECKED STEAMERS.

	Turret.	Single-deck.	Part-awning.
Dimensions—			
Length between perpendiculars ...	297 ft. 0 ins.	297 ft. 0 ins.	297 ft. 0 ins.
Breadth, moulded	39 „ 9 „	39 „ 9 „	39 „ 9 „
Depth, moulded	24 „ 1 „	23 „ 6 „	20 „ 10 „
Depth of hold	21 „ 7 „	21 „ 0 „	18 „ 4 „
Draught ex keel	19 „ 6 „	19 „ 6 „	19 „ 6 „
Freeboard and reserve buoyancy—			
Summer freeboard to statutory deck-line	10 „ 3 „ to turret 4 „ 8 „ to harbour-deck	4 „ 2¼ „	8 „ 10¾ „
Load displacement in tons	5,230	5,230	5,230
Coefficient of displacement	·795	·795	·795
Reserve buoyancy in tons	2,282	2,512	2,956
Percentage of reserve buoyancy ...	30·4 %	32·4 %	36·1 %
„ „ „ required by freeboard tables for flush-deck vessel corrected for the summer load-line ...	27·41 %	27·14 %	25·82 %
Deadweight—			
Total deadweight at load draught in tons	3,790	3,640	3,650
Ratio of deadweight to load displacement, per cent.	72·5 %	69·6 %	69·8 %
Deadweight for cargo at load draught...	3,490	3,340	3,350
„ coal and stores at load draught	300	300	300
Capacity—			
Measurement capacity for case cargo in cubic feet	170,040	167,559	185,099
Rate of stowage for case cargo in cubic feet per ton	48·7	50·2	55·3
Measurement capacity for bulk cargo in cubic feet	180,200	175,226	191,320
Rate of stowage for bulk cargo in cubic feet per ton	51·7	52·5	57·2
Cubic feet of case measurement per ton net register	123·6	112·0	118·8

TURRET-DECK CARGO STEAMERS.

TABLE A.—*Continued.*

	Turret.	Single-deck.	Part-awning.
e—			
age, under-deck	1,977	2,108	1,836·72
" gross	2,211	2,337	2,484·40
" net register	1,376	1,495	1,557·04
" under-deck coefficient ...	·771	·845	·843
tio of net register to deadweight cargo	39·5 %	44·7 %	46·0 %
ngth—	29 ft. 9½ ins.	23 ft. 6 ins.	28 ft. 1 in.
epth of girder for longitudinal strength	1,236	1,122	—
ectional area of material in sq. inches	115,030	82,776	—
Moment of inertia of section	3,860	3,522	—
" " + depth of girder...			—
Assumed bending moment	44,500	44,500	—
$\frac{\text{length} \times \text{displacement}}{35}$	4·39	4·627	—
Strain on keel in tons	7·249	8·004	—
" gunwale in tons			
Stability—	2·75	2·75	2·75
Approximate initial stability	·75	1·70	2·41
Maximum righting lever	1·02	8,891	12,604
Maximum righting moment	3,922	48°	53°
Angle at which maximum is reached ...	5,230	30°	36°
Angle at which hatches touch water ...	23°	92°	99°
Range of stability	61°		
Power—	47°		
Speed in knots per hour...	100°	9	9
Indicated horse-power		1,050	1,05

TABLE B.

LIST OF TURRET-DECKED STEAMERS ALREADY BUILT OR NOW BUILDI

Name.	Registered Dimensions.	Gross Tonnage	Class.	Builders
S.S. "Turret" ...	280·3 × 38·0 × 20·4	1,970	Veritas ...	W. Doxford &
" "Turret Age"	311·0 × 38·2 × 21·8	2,232	"	"
" "Turret Bay"	297·0 × 40·0 × 21·9	2,211	"	"
" "Bencliffe" ...	297·0 × 40·0 × 21·9	2,210	Veritas & Lloyd's	"
" "Progressist"	340·0 × 45·5 × 23·5	3,188	Veritas ...	"
" "Royalist" ...	340·0 × 45·5 × 23·5	3,188	"	"
" "Turret Bell"	297·0 × 40·0 × 21·9	2,211	"	"
" "Hopedale" ...	280·0 × 38·2 × 18·8	1,730	"	"
Screw steamer (building)	280·0 × 38·2 × 19·5	1,790	"	"
" "	195·0 × 31·0 × 12·8	670	"	"
" "	253·0 × 44·0 × 16·7	1,640	"	"
" "	253·0 × 44·0 × 16·7	1,640	"	C.S. S
" "	297·0 × 40·0 × 21·9	2,211	"	
" "	300·0 × 43·0 × 24·2	2,750	"	
Total	14 steamers of	29,641	Gross tons	

ove vessels have also received the highest

DISCUSSION.

Mr. Theo. W. Doxford (Past-President) took the chair on account of the President having to leave to catch a train. He explained that as soon as his firm learnt that Mr. Kendall was preparing a paper on this subject they dropped the intention they had had of reading a paper upon it themselves, and for this reason, that they felt Mr. Kendall, with the experience he had had as representing the Bureau Veritas from the commencement of the type, would be able to prepare a paper with less bias than themselves, seeing the personal interest they had in the subject. He did not propose to take this opportunity of entering upon the merits of the question at all; but there was a gentleman present representing the British Corporation who had also been connected with them—as representing that society—from the beginning, and he thought they would all be pleased to hear what he had to say upon the subject. He believed that Mr. Courtier-Dutton had come specially from Glasgow to be there that night, and might not be able to be present at the adjourned discussion. They personally owed a great deal to both of these societies for the assistance they had given them in the development of the turret type of vessel.

Mr. W. T. Courtier-Dutton said he thought Mr. Kendall gave a very interesting account of the value of the turret-decked type of vessel as a deadweight and bulk carrier, also of the structural advantages of the form, and the better distribution of material possible on account of that form. Before, however, referring in detail to the structure itself, he should like to be permitted to make a few personal remarks with a view to avoiding what he felt might be an unfair impression of the British Corporation with regard to the part which they had taken in the development of these vessels. So far as he (Mr. Courtier-Dutton) knew Mr. Kendall was not associated with the Bureau Veritas at the time those vessels were first considered, and he had therefore, unwittingly, done the British Corporation some slight injustice, not so much in what he had said as in what he had left unsaid. He thought Mr. Doxford would bear him out when he said that the Corporation from the first fully appreciated the structural possibilities of this type. The present vessel was very different from the first conception. In the midship section first submitted to, and approved, he believed, by the Bureau Veritas, the turret itself was simply a continuous hatchway, fore and aft, with hatch covers coming down in the usual way to the

sides of the turret, the upper part of the turret topside forming, practically, the coamings. The section was submitted to the Corporation, and he thought they were of some assistance in altering that form to the condition it had now assumed. They pointed out to the builders that it would be a distinct advantage to have a stringer plate, which would provide a very rigid corner at the upper part of the turret, forming a stronger member for the top of the girder, and at the same time providing a gangway or working platform for the vessel. It was also arranged at that time that the web frame fitted at intervals should be carried right round at the level of the harbour-deck, and so form a continuous girder right round the ship. This, he thought, was a very important point, and was embodied in the vessels as now built. He might add that the necessary calculation of strength, reserve buoyancy, and freeboard were made by them at a very early stage, and that they had assigned the freeboard to all these vessels. Before leaving that, he might say that all admired the zeal with which his friend, Mr. Gravell, a short time ago very properly and justly, he thought, claimed on behalf of his society that they were the first to take in hand the question of the construction of these vessels, and therefore he was sure that Mr. Gravell and Mr. Kendall, the able representatives of the Bureau Veritas, would not grudge him the little explanation of the part the British Corporation had taken in the development of the turret vessels. Coming now to the structural strength of these vessels, he considered that this great girder on the top of the harbour-deck, giving, as it did, a rigid inner edge to the harbour-deck plating, prevented any possibility of horizontal deflection at the harbour-deck, and with the two sides of the turret tied together at any reasonable intervals, the usual close spacing of beams became unnecessary. For the same reason, considering the great depth of the girder, about 5 feet in the case of the vessel to which Mr. Kendall refers, but of a much greater depth, about 6 feet 6 inches, he thought, in the model before them vertical deflection was also practically impossible, and a close spacing of stanchions was unnecessary, and it became possible to adopt a system of transverse framing in which all the work was transmitted to strong web frames at intervals of about 20 feet. This was an undoubtedly better distribution of material, and more scientific, than the ordinary close spaced web frames. The principal development seemed to lie in the extension of the principle of longitudinal framing. He quite agreed with Mr. Kendall as to the increased transverse strength obtained by rounding the top of the vessel. Another advantage seemed to him (Mr. Dutton) to be the unbroken continuity of strength all fore and aft. The

system of framing was not interfered with, all that was necessary was to have a sufficient number of strips of plating to ensure the sides being tied together, and this was simplified in view of the resistance to deflection to which he had referred. Mr. Kendall mentioned a case of the partial-awning-deck type as probably the most successful rival of the turret-deck as a freight carrier, though not equal to it, and his figures seem to bear out that view. He could only say that he was sorry Mr. Kendall could not bring forward a better designed vessel as an example; this hybrid type of boat being, in his opinion, unscientific and non-mechanical. On the question of stability attention was called in the paper to the very great range of stability which these vessels possessed, no doubt a very important factor in considering the ultimate safety of the vessel. The initial stability was comparatively small, and while with the modern vessel of broad beam and box section, it was not desirable to have too much of this initial stability, on the other hand, there was the possible danger of having them too easy. He did not consider, for instance, speaking generally, that it was desirable to load these turret vessels to the point where the area of the load water-plane would be reduced by the rounding over of the side, and in the assignment of their freeboards this point was fully considered. Of course this matter, again, might be modified by the result of careful stability calculations. In comparing the reserve buoyancy of the turret-decker with the ordinary vessel, Mr. Kendall perhaps gave an unfair advantage to erections of the latter, which he credits with actual surplus buoyancy; for while the turret itself provides reserve buoyancy the erections have a value assigned on account of the assistance they give to a vessel in a sea-way. As a matter of fact, bridges not fully enclosed might be a source of danger to the vessel by holding a body of water which could not be got rid of readily. He agreed with Mr. Kendall that the present value for reserve buoyancy assigned to turrets seemed inadequate, but would remind him that the regulations as they stood at present were tentative. This brought him to the last paragraph in the paper, namely, the statement that there were people who advanced the astonishing argument that the superiority of the turret vessels should be disallowed and put an end to because the ordinary vessel would be unduly handicapped in the race for business; or, in other words, that none should advance because others might be left behind! This might be intended as a snub to the builders, who, he believed, were able to take care of themselves; or it might be meant as a rebuke to the register societies who had the audacity to advance a little out of the beaten track.

Mr. S. O. KENDALL asked leave to say in regard to his remark upon what he (Mr. Kendall) had *not* said with respect to the part the British Corporation had taken in the classification of the turret vessels, that the same might also be said by the Bureau Veritas, for he had not referred to the part either took in the details of the turret vessels; and he certainly had no desire to minimise the importance of the part taken by the British Corporation in co-operation with the Bureau Veritas, in the development of the details of these vessels.

Mr. COURTIER-DUTTON said he was very much obliged to Mr. Kendall for the remarks he had made. He had no desire to press the point, lay any stress upon it; but he felt that as the paper would be embodied in the *Transactions* of the Institution the little explanation which had been made would prevent some injustice being done to the registry he represented.

Capt. JOHN NICHOLSON said the few remarks he had to make related purely to the practical part, in which he had had very great experience. He did not fall in with the views of Mr. Kendall; but before discussing the practical part, let him explain away a point made over the first voyage of the "Turret." It had been stated that Captain Petersen, whom he was glad to see present, made the voyage in the vessel. He thought Captain Petersen would tell them he was glad to land at the Western Islands. He would be able to correct him if he was wrong. The advantage claimed principally was the saving of weight in the hull with efficiency, but as that was more of a scientific question, he would pass on. A second advantage was the alleged greater safety in navigation of the turret-deck steamer, that in heavy weather it would be much safer and easier to navigate than the ordinary type of cargo steamer. He was sorry to think that in dealing with this vessel Mr. Kendall had taken an almost obsolete type of vessel for comparison. He was comparing a single-deck ship similar to those built in the early seventies. He (Captain Nicholson) thought it an unfair comparison. Owing to the fact that that class of vessel was quite unworkable at the present time, it was well known that very great improvements had been made in the ordinary cargo steamers during the last fifteen or twenty years, and at the same time bear in mind that Mr. Kendall was supposed to be dealing with the so-called most modern type. The vessel he should have dealt with was the improved part-awning-deck ship, which was far superior to the turret ship. He touched on the question of height above the water-

line of a part-awning-deck vessel in comparison with a turret of a similar size, and gave the height about 8 feet 10 inches after allowing for round of beam. To say nothing of the hatches and other substantial deck erections, the height would be nearer 10 feet. Add to this the sheer forward of, say, 7 to 7½ feet, would give a resisting power at the very strongest part of the vessel of nearly 17 feet. Then take into consideration that the flotation given in the other part of this vessel represented the full width of beam, say, about 40 feet. This, in his opinion, would give them a reserve buoyancy and lifting power of more than double that of the "Turret," with her 10 feet 3 inches to the top of the turret-deck and 4 feet 8 inches to the so-called harbour-deck. He would assume this latter vessel, say, the "Turret," was crossing the Atlantic ocean and loaded down to her usual draught. She met with a very heavy gale and a wave rolling between 40 to 50 feet high, and probably running at the rate of 10 to 11 knots, in such weather she would be head to sea, steaming say, 1 to 1½ knots, she would have to face a force equal to about 11 knots, and owing to her want of sheer and of sufficient buoyancy forward, she would not rise in time, hence the mighty Atlantic roller would pass over her. If she had time, and the wave was going slowly, which it would not be, she would rise right enough, so would a London barge if she had time. They performed their work splendidly, but their owners did not attempt to send them across the North Sea when they knew very well that if they came in contact with waves of any height they would be almost certain to founder. He believed the "Turret" to be sufficiently seaworthy in every respect to pass safely through short, choppy seas. But he held that it would be practically impossible to raise her out of such a sea as he had mentioned without additional flotation forward; the sea was bound to go over her, and she would not survive many such seas. Now, he maintained, that the awning-deck vessel—Mr. Kendall's other vessel, the flush-decked one—he would let her drop, and would have nothing to say regarding her; but if the awning-deck vessel was properly constructed she was perfectly safe. As to the question of capacity that was a matter in which he could not exactly follow Mr. Kendall. He told them that the case capacity was 48·7. If he had taken the measurements from the outside of the spar ceiling, and made fair allowance for the deck beams and pillars, he could not agree with him. He thought it would turn out 45 or less. Had Mr. Kendall made any allowance, when speaking of case cargo, for the rounded sides of the turret, as there was no doubt there would be a considerable loss, more particularly if the

were large ones? In stowing cargo in the ordinary steamers [illegible] en, Kendall said they could not fill between the beams. He thought [illegible] ght would be better left alone. Mr. Kendall evidently never had seen [illegible] een ordinary vessel stowed, for the greatest care was always taken to have [illegible] ave spaces between the beams properly filled, particularly with grain [illegible] ain goes. He came to a point he was really amused at—the deck cargo o[illegible] of turret ship. As far as he had seen the turrets, they had rails runnin[illegible] ng ong, but saw nothing at all there for fastening a deck cargo to, and [illegible] if deck cargo was put in in the ordinary way, he felt sure the first ti[illegible] me the ne vessel got into a sea running 5 or 6 feet high, away would go t[illegible] and deck cargo, for the sea, striking the rounded side, would roll on solid, a[illegible] an thus lift the timber with the greatest ease, whereas if it was striking [illegible] hey ordinary ship it would break, and only the spray would go over. They [illegible] If called it a harbour-deck; he called it a sea-deck—very much sea. If [illegible] nd the lashings were not sufficient to resist the whole flotation they were bound [illegible] the to go, as there was nothing to stop them, and the rounded sides of the [illegible] vessel would materially assist this operation. With regard to the advantages claimed for the hold pillars, he saw nothing in this, as one of the pillars used in the turret would occupy a space equal to three or four ordinary ones. Then there was the question of deadweight, taking value for value. As a matter of fact, he knew partial-awning-deck ships carrying as near as possible the same weight in proportion to the size. It must be patent to every one that the turret vessel would not carry her full deadweight with many bulk cargoes. Supposing she had to load coal, measuring from 51 to 55 feet per ton, it was easy from Mr. Kendall's figures to show she would have to go very short. In general cargoes she would be almost entirely excluded, and in bad weather it would not be possible to put on deck cargoes. The only gain was in net tonnage, for the actual price of the turret vessel was no less than the ordinary vessel, the saving was in the net tonnage. They were sacrificing the efficiency and stability, and in his opinion practically gaining nothing. He maintained the first thing the shipbuilder ought to take into consideration was a ship's efficiency and stability; no ship ought to be sent to sea until thoroughly efficient, and without risk or danger from any voyage she might have to make. If he were asked, "Should this vessel go across to the Baltic?" he would say "Yes," for she would only encounter short cross seas; and indeed she might be sent on any trade where only short choppy seas were encountered; but in the Atlantic, with its great rolling waves, then would come the tug of war, and it would then be proved whether she was the type of steamer for the future.

He thought so far as regarded the stability claimed for the turret on account of her rig there was absolutely nothing, as cargo steamers were very lightly rigged now and had been for some years. Last, but not least, the getting out of these boats! He had seen this vessel in dock, and wondered how were these boats to be got out in a gale of wind, and how, if they got them out, were they going to get the men into them? He held it would be practically impossible, owing to the formation of the vessel's sides, assuming that they were able to launch them. He hoped they would never have to be used, for he was sure that in heavy weather the men would never get into the boats, even on the lee side, the range or roll of the waves would be liable to throw the boats on the rounded sides of the so-called harbour-deck, and if so they would certainly capsize; the great safeguard for keeping a boat in a safe position alongside in heavy weather being that they had the upright side of the vessel to guide them.

The CHAIRMAN (Mr. W. T. Doxford, Past-President) said that it was now too late to continue the discussion that night, but expressed his pleasure in hearing Capt. Nicholson express so strongly his views upon this question, for nothing brought out the advantages or disadvantages of any subject better than a strong opposition view strongly expressed. No doubt next meeting some gentleman who had had practical experience of these vessels at sea might be able to reply to Capt. Nicholson, who had only spoken from his experience at sea in other types of vessels, and perhaps he might be able some day to see his error. There were many things about these vessels Capt. Nicholson had not seen, and he (Mr. Doxford) would have great pleasure if he could come and see the turret vessels now building, and thus be the better able to understand their details. They might not be able to convince him he was wrong, but there was always a chance of their doing so.

Capt. NICHOLSON said he would have great pleasure.

The meeting then adjourned.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

ELEVENTH SESSION, 1894-95.

PROCEEDINGS.

SEVENTH GENERAL MEETING OF THE SESSION, HELD IN THE LECTURE HALL OF THE ATHENÆUM, WEST HARTLEPOOL, ON SATURDAY EVENING, APRIL 6TH, 1895.

ALDERMAN THOMAS RICHARDSON, B.A., J.P., PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, held in Sunderland, on March 12th, which were approved by the members present, and signed by the President.

The ballot for new members having been taken, the President appointed Messrs. J. R. Fothergill and G. H. Baines to examine the voting papers, and the following gentlemen were declared elected:—

MEMBERS.

Campbell, John M., Shipyard Manager, 4, Winchester Terrace, Newcastle-on-Tyne.

Fisher, John, Shipbuilder, Park Side, Jarrow-on-Tyne.

Fox, William, Engineer, 9, Winfield Terrace, Chester Road, Manchester.

Renton, John, Marine Surveyor, 1, Akenside Hill, Newcastle-on-Tyne.

MEMBERS (LATE GRADUATES).

Armstrong, William S., Shipbuilder, 8, Friedrickstrasse, Kiel, Germany.

Fairbairn, James, Engineer, 54, Amberley Street, Sunderland.

ASSOCIATE.

Wade, Wentworth S., Marine Superintendent, 104, Whetstone Lane, Birkenhead.

GRADUATE.

Brown, George M., Engineer, 243, Albert Road, Jarrow-on-Tyne.

NOMINATIONS.

The PRESIDENT intimated that in accordance with Article X. of the Constitution, the following gentlemen would retire from the Council :—President—Ald. Thos. Richardson, B.A., J.P. ; Vice-Presidents—Mr. J. Gravell, Sir William Gray, and Mr. A. Taylor ; Ordinary Members of Council—Messrs. M. C. James, W. C. Mountain, T. Mudd, J. Patterson, and W. G. Spence ; Hon. Treasurer—Mr. G. E. Macarthy.

In accordance with Bye-law 11, the PRESIDENT, on behalf of the Council, nominated the following gentlemen, to be balloted for, to fill up the vacancies :—President—Ald. Thos. Richardson, B.A, J.P. ; Vice-Presidents (three to be elected)—Mr. John Gravell, Sir William Gray, Mr. D. B. Morison, and Mr. James Patterson ; Ordinary Members of Council (five to be elected)—Mr. W. H. Dugdale, Col. T. English, Messrs. J. B. Furneaux, Robert Readhead, C. J. Seaman, and John Walker ; Hon. Treasurer—Mr. G. E. Macarthy.

Further nominations were open to the meeting, but none were made.

CONSTITUTION AND BYE-LAWS.

The PRESIDENT, on behalf of the Council, gave notice that at the Closing Business Meeting, to be held in Newcastle-upon-Tyne, on May 14th, he would move that the following alterations and additions be made to the Articles of Constitution and the Bye-laws, the proposed alterations being in italics :—

Add to Constitution VIII.—"*All such compositions shall be deemed to be capital moneys of the Institution.*"

Bye-law 6.—For "first of June" read "*first of August,*" as under:—

Bye-law 6.—All subscriptions shall be payable in advance, and shall become due on the 1st of *August* each year. Any Member, Associate, or Graduate wishing to retire from the Institution shall continue to be liable for his annual subscription until he has given formal notice of his retirement to the Secretary, which notice must be given on or before the 31st of August in each year. Application for membership may be made at any time during a session, and the subscription shall cover the membership up to the 1st of *August* following.

Add to Bye-law 28.—"*The President shall, ex-officio, be a member of all Committees.*"

Add to Bye-law 31.—"(4) *A Graduates' Award Committee, to consist of five members.*"

Bye-law 43.—For "the 31st of May," read "*the 31st of July.*"

Insert the following new Bye-law after Bye-law 44:—"*The Finance Committee may, with the consent of the Council, invest in the names of the appointed Trustees of the Institution any moneys, not immediately required for the purposes of the Institution in, or upon any approved securities.*"

The discussion on Mr. Henry Foster's paper "On the Application of the Electric Arc to Machinery and Boiler Repairs, etc.," was resumed and adjourned.

The discussion on Mr. S. O. Kendall's paper on "Turret-deck Cargo Steamers" was resumed and adjourned.

Mr. G. H. Baines's paper on "The Metric System of Weights and Measures" was deferred to an extra General Meeting, to be held in Sunderland, on April 24th, 1895.

ADJOURNED DISCUSSION ON MR. HENRY FOSTER'S PAPER "ON THE APPLICATION OF THE ELECTRIC ARC TO MACHINERY AND BOILER REPAIRS, ETC."

Mr. H. Macoll said there could be little doubt that Mr. Foster in his interesting paper had put before them a most valuable appliance, and one that would become of steadily increasing importance. It was therefore a matter of regret that, although such a fitting as a boiler furnace might be welded from end to end with approval by one of the Government Departments which was supposed to concern itself with the safety and efficiency of marine engines in vessels carrying passengers at sea, yet on no account must the smallest portion of the steel working parts of a marine engine be welded if the structure was to obtain a passenger certificate. And as that was a matter specially affecting marine engineers he would suggest for consideration whether it was not advisable, and strictly within their province, as an Institution, to appoint a representative committee with powers to endeavour to bring about a more satisfactory understanding than was the case at present.

ADJOURNED DISCUSSION ON MR. S. O. KENDALL'S PAPER ON "TURRET-DECK CARGO STEAMERS."

Mr. THOMAS W. WATSON, continuing the discussion, said on page 213, advantage 6th, it was claimed that by providing a high navigating platform it was possible to dispense with sheer and still retain the necessary reserve buoyancy, thus greatly simplifying the construction, and at the same time reducing the tonnage to a minimum. Just so; reduction of tonnage seemed to be the great object the up-to-date shipbuilder had in view. Everything possible must be sacrificed to this modern Moloch. Even sheer—and if the register tonnage could only be reduced and the deadweight capacity retained, the comfort of the seamen and the appearance of the ship need not be considered. This seemed to him to be a mistake, and no living scientist would ever convince him that any amount of righting lever or high initial G.M. would make a flat-bottomed, wall-sided, straight-lined, turret-deck steamer equal either in comfort or sea-kindliness to a modern single-decker with a decent rise of floors, a small bit of tumble home, and just enough sheer to swear by, though the more sheer she had the better she would be. They had a decent ship in the first "Lustrum" of the '80's—well built, well found, and well decked; but since that time they seemed to be trying to find out how far off that very safe ship they could get to be still safe. In Table A, page 223, the turret freeboard is given as 4 feet 8 inches, percentage of spare buoyancy, 30·4; single deck, freeboard, 4 feet 2½ inches, with 32·4 per cent., an apparent difference in favour of the single-decker of only 2 per cent.; but if they referred to the required freeboard for this class of vessel, corrected for the summer load-line, it was really 2·27 per cent. in favour of single-deckers, or only $\frac{1}{5}$th of excess buoyancy in the turret-deck against $\frac{1}{6}$th of excess buoyancy in the single-decker, *i.e.*, over the percentage of freeboard required for summer load-line. In Table B, the S.S. "Bencliffe" was the only one marked Veritas and Lloyd's. Would Mr. Kendall tell them, if it was not asking too much, if the "Bencliffe" differed in any structural dimensions from the other seven? And, if so, was she stronger or weaker, or, if he liked it better, was the scantling heavier or lighter? It seemed to him from the particulars given on page 211, paragraph 2, Plate LX., that the safest position of the turret-deck steamer was an angle of about 30 degs. from the upright. He

e advantage of this, as he took it ships were meant to
n upright position; at any rate he knew from experience
re comfortable when they were upright; they get along
thout so much wear and tear of machinery, hull, and muscle
Just one other point—the putting out of lifeboats (see
That was in any ship a dangerous operation in stormy
ut must be exceptionally so in this case. There were two keys
from the davits, two pins to remove from the chocks, and the
be lowered gently to the length of the span. It was perfectly
the pins and keys must be removed simultaneously, or there
be a smash. To do this required four men. When the boat fell
of the chocks she would naturally swing outwards, and if they
red to Plate LXII., and looked at the position of the boat after she
ng in, they need not be surprised if they found the side stove in.
ppose her clear of the chock intact. How were the men to get in?
ad they to swarm along the span to the davit head and slide down the
alls? He did not like this boat-lowering arrangement, it had a very
dangerous appearance to his mind, and he would further like to ask if
any difficulty had been experienced, either in putting out a boat, taking
one in, or in getting a pilot on board at sea? Load displacements,
coefficients, bending moments, strains on keels and gunwales, righting
levers, and stability, he would leave to his shipbuilding friends.

Capt. W. PETERSEN said he should like to lay before the Institution
some of his experiences both as a ship manager and shipmaster in con-
nection with the type of vessel treated in Mr. Kendall's paper. He felt
also that Capt. Nicholson's remarks at the last meeting in Sunderland
called for some reply or criticism from him, as one of the firm that first
introduced this style of vessel, and the first to command the first turret
steamer on her maiden voyage. He might say that before his firm
contracted with Messrs. Doxford for the first turret steamer they went
very carefully into the commercial question, and it did not take them
very long to find that the advantages claimed were there. These, he
was pleased to say that day, had been more than realised. The various
commercial points could be guaranteed within a very small margin by
the builders, and it would not, therefore, on this score appear that his
[illegible] taken such a leap in the dark as was generally supposed when
[illegible] contract for the first turret steamer. The question
[illegible] point which actually remained to be
[illegible] it should not take a sailor

echnical knowledge, that Mr. Kendall was rather within beyond in his statements referred to by Capt. Nicholson. sides, instead of being a disadvantage had proved a distinct part from the increased transverse strength obtained; n rolling on the half-round seemed to expend its forces e reaching the navigating platform, and he had never his own experiences, nor by reports his firm had had from the aptains and crews, that a green sea ever broke over any part of t-deck. This statement would, no doubt, amuse his friend Capt. on, and other gentlemen of equally incredulous disposition, but they doubted his statement, as an interested party, he hardly it was fair to treat with suspicion and incredulity the statements by all the captains, officers, and crews who had had experience of turrets throughout nearly two and a half years. He would be glad place before anybody, who would take the trouble to come to his office, umentary evidence of all he stated there, and place it absolutely beyond ubt. The turrets had been engaged almost exclusively in the Atlantic rades, and he need not tell many there that, as a rule, they had not to go seeking for gales of wind very long in these regions, especially in the winter time. He would be very glad to give anyone an opportunity of a trip in a turret across the Atlantic, and treat them well, and he could assure Capt. Nicholson, that although he understood he had not been at sea (in the real sense of the word) for upwards of twenty-three years, he would find the motion in a sea-way of the turrets so gentle that it would not disturb his gastric arrangements. On the maiden voyage of the "Turret" she was subjected to a very severe test, when crossing the Atlantic in the depth of winter, and in the severe gales she passed through more than one good vessel succumbed; for instance, the S.S. "Naronic" of the White Star Line was lost in one of these gales. Depending upon the scientific calculation of strength, spare buoyancy, and stability, he had every faith before starting upon the voyage that the "Turret" would prove a good sea ship, and his suppositions were more than realised. He had at first some difficulty in getting a crew to remain on board at Cardiff, and to commence with, seven of them deserted, they being no doubt influenced by the gruesome predictions then made by people who made it their business to run the type down. Although they had conclusively proved that day that these people were wrong, yet many of them were not men enough to admit it, and many others, especially those with flects of obsolete types, found it contrary to their interest to admit

it, and they still kept drawing upon their inventive faculty and imagination rather than face facts. The first crew not only soon found out that the "Turret" could float in a heavy sea-way, but that she behaved with most exceptional ease, in spite of her being loaded down to her winter marks with a most trying cargo, consisting of railway material and patent fuel. The same crew nearly all remained in the "Turret" for about a twelvemonth, and some of them, after being paid off, went into the other turrets they were then building. In fact, they had several hands standing by at present waiting to go into the new vessels now building, who had served only in turrets since the first voyage of the S.S. "Turret." He might explain that it had been arranged with his partner (and Messrs. Doxford would testify to this), that if he considered that a sufficient test of the "Turret's" sea-going qualities had been made by the time he was near the Azores, he should land there, as other important business called for him at home. In fact, negotiations were pending in Paris with a firm there to build a turret to carry oil in bulk, as it was their opinion—an opinion he still maintained—that turret ships would make the finest bulk oil carriers ever known. He might also add that on his arrival home his firm contracted with Messrs. Doxford for the second turret before the arrival of the first one in Tampico, where she proceeded after landing him at the Azores. He made these statements to show that Capt. Nicholson was quite right, when he said in Sunderland that he thought he (Capt. Petersen) was pleased to land at the Azores. Whether he meant it sarcastically or not he did not know, and did not care, but the fact remained that he was very pleased indeed to have made sure by that time (after passing fourteen days in the Atlantic) that the "Turret" as a sea-boat had more than realised his expectations. The turret steamers under their management had, as he said, nearly exclusively been in the Atlantic trade ever since, and crossed all times of the year, both in ballast and with deadweight and other cargoes on board, and so far their experience had been, that the satisfactory experiment of the S.S. "Turret" had been repeated in every single instance, and when he said that they had never had £10 worth of damage done above decks, it ought to be sufficient evidence of their excellent sea qualities. He might now turn to another and just as important a consideration, namely, the commercial value as compared with the older types. Capt. Nicholson remarked that the cost of turrets was no less than ordinary vessels. He did not know where Capt. Nicholson got his authority from, but he could assure him that he was wrong again. In every case of building these boats up to the present,

bare fact of such an attempt being made. He (Capt. Petersen) could not conceive that any really practical man who had ever seen a turret vessel could advance such views, even if he had no knowledge of the real facts of the case. The harbour-deck running fore and aft on both sides of the vessel affords a large space for stowing wood and other material. But nothing showed so well as facts. On three different occasions they had carried wood deck loads upon their turret boats. The "Turret Bay" and "Turret Age" carried about 130 standards of deals each down to River Plate from Montreal in winter, and they both arrived, making good passages, notwithstanding the bad weather they encountered in the North Atlantic, without losing a single board. The S.S. "Turret" also carried a deck load of pine timber from Pensacola to the Adriatic in the depth of winter without losing any. She had about 70 standards on deck. This same steamer further carried successfully on deck fifteen iron girders, 74 feet long, weighing 23 tons each, from Baltimore to the West Indies in 1893. He thought these facts proved that turret vessels can carry deck cargoes, and safely. The turret erection was especially useful in keeping on deck loads, and as the seas generally struck the outside of the cargo it was next to impossible to wash it off the harbour-deck. It could be secured, indeed so as almost to be part of the ship's structure. He should like to say, in regard to Mr. Watson's remark about the comfort of the crew, that if it was intended to refer to the turret, they had more accommodation for the crew in them than he had seen in any other vessel. They had set aside for the crew a mess-room of very considerable cubical capacity, and, more than that, they had a bath-room for the men in connection with the lavatory, so that there was every comfort men could reasonably expect. He had not seen better accommodation even on passenger ships. With regard to getting the boats out, that was a matter about which there seemed to be some doubt, and Capt. Nicholson having referred to this subject in quite an emotional strain, he (Capt. Petersen) could enlighten them on this score, and set their minds at ease. After getting through the gales, he experimented at the Azores (although there was no hurricane blowing at the time, there was a very good roll on), and he might tell them, that having the falls ready, two men launched a boat in very little over two minutes. The arrangements for launching the boats were very easy, and they could pull the boats up much easier by running the falls along the winches. It did not require more than two men to launch a boat, the davits fell down by their own weight, and they could get easier into the boats than they would imagine.

On the lee side they could almost step into them, and they were kept clear of the ship's side by the projected davits. They knew the difficulty in launching boats in ordinary ships, and the trouble of keeping them clear from the side and preventing them getting smashed in a rolling sea before the crew could get into them. Then they generally had to get into them by the falls, as they could not, as a rule, get down the side ladder in heavy weather. Now, the arrangements on the turret vessels were preferable to the old-fashioned davit, the difficulty of launching and getting into their boats being very small indeed. He would not occupy their time in saying any more on the subject. He did not know, speaking from a commercial point of view, whether he had any reason to thank Mr. Kendall for his very able paper. Speaking as a turret shipowner, he (Capt. Petersen) thought he gave too much information to the shipowning public in these days of hard competition; but, speaking generally, and as a member of this Institution, he might have set forth a good many more advantages. He had, of course, written more from a scientific point of view than really with a view of going into full details of the commercial question, and he (Capt. Petersen) thought they were bound to admit that he had treated the subject in a most able and impartial manner, for which their very best thanks were due to Mr. Kendall.

Mr. G. W. Sivewright said there was considerable credit due to Messrs. Doxford for the pluck they had shown in building ships of this peculiar design. In his opinion, it took a great deal of courage to depart from any well-known type, and in placing the turret ship upon the market they had hit out straight from the shoulder, and he hoped if the criticism was of the same description that night they would consider it was for the benefit of the design. He noticed that the sketches supplied by Mr. Kendall differed from the original turret ship illustrated in *Engineering*. For instance, the engines, instead of being aft, were now placed amidships, and he considered this would be a great advantage, as it would assist the trim of the ship, more especially on long voyages. This also had reference to the addition of a plate bulwark now placed amidships, and, in his opinion, if this was carried right fore and aft it would be a benefit to the ship. When this design of vessel was first talked about he might say that as a shipbuilder and shipowner it came upon him as a surprise, for, according to the reports, they were going to get such a wonderful ship that no other vessel would be able to trade in the market with the turret type; but after going most care-

fully into the design, he had come to the conclusion that the builders had taken an enormous amount of trouble in trying to make the ship's equipment as much unlike a ship as possible, and they might call her a turret ship, or any name they pleased, but, after all, she only resembled a single-decker suitable for deadweight trades. To bear out his contention, he would call their attention to a section he had prepared of an ordinary single-deck cargo boat in comparison with the turret ship. (See Plate LXIV.) They would see he (Mr. Sivewright) had shown a modification of Price's patent hatches, and by comparing the two sketches, in his opinion, there was practically no difference between the two types of ships, but, if anything, he considered the real single-decker was the better vessel. He did not think any credit could be claimed by the designers of the turret ship for originality in stepping the hatch coamings back from the side of the trunk hatch, as this was not novel. They would also notice from the sketch of the single-decker that there was a bulwark shown, which he considered would be a great advantage, and he was quite sure this opinion would be confirmed by the majority of seafaring men. They had heard the remarks from Capt. Petersen and his different captains about this type of vessel, but they had failed to show that these vessels had done anything different from what anyone would expect an ordinary cargo boat to do, and he thought it might be possible to get different opinions from people who had sailed in these vessels. There could be no doubt that Mr. Kendall, being a shipbuilder and writing a technical paper, would suffer from what nearly all shipbuilders have to contend with, the want of sufficient shipowning knowledge to give particulars of the trading of the ship. He contended there was far too much assumption in Mr. Kendall's paper, if Mr. Kendall would pardon him for saying so, and they were asked to take too many statements on trust. If they referred to the end of the paper they would see it was stated "that the turret type would be earning a very fair profit on freights which would hardly be remunerative to the ordinary type of steamer," but when a statement of that kind was made there should have been some voyage accounts supplied to prove it, and then they would have been better able to discuss the turret type of ship on its merits; but not having these particulars by them, it would very much prevent an exhaustive discussion of the paper on its true merits, for the commercial results were the proper test. Considerable attention had been drawn to the turret ship having a small net tonnage, but he really did not see anything extraordinary in the tonnage in comparison with the cubic capacity. A small net tonnage was very easy to get when they only

wanted a deadweight boat. He observed that the turret ship worked out to 124 cubic feet per net register ton, and he might state that he (Mr. Sivewright) had built ships to 130, with 268 tons permanent bunkers, but special means were taken to get this small tonnage by building the ship with deep frames and other arrangements. If owners were content to have a deadweight boat, all well and good; but it was his contention that when they got a ship above a certain size they could not rely upon the deadweight trade alone, and they were bound to go into general trading; for instance, he considered the turret ship was not suitable for Eastern trading, as there would be many general cargoes of such a nature that when the vessel was loaded she would not be down to her marks. He believed it would only be in the heavy deadweight cargoes that the turret ship would be able to profitably trade, and he should liked to have had some particulars of the turret ship loaded with, say, light north country coal, barley, rice, Bombay cargo, case oil, etc. Although Mr. Kendall in his paper had not got an up-to-date semi-awning-deck vessel for comparison with the turret ship, he was pleased to see it was admitted that the turret ship was not such a good cubic capacity boat as the semi-awning-deck vessel. He was sorry that Mr. Kendall, in the comparison of the strength of the two types, had not given some particulars of the semi-awning-deck vessel, but had left the columns blank. He was quite sure that with the strong topside plating with which these vessels were now built, backed up with strong sectional framing, it would have been interesting information for comparison. In looking over the curves of stability he could not help being struck at the peculiar curve of the turret ship. He considered it was the most extraordinary curve he had ever seen. It appeared to him, from the particulars of the curve, that the only safe place for the vessel was on her broadside. He thought it was hardly fair to take into consideration, in the case of the turret ship, the central hatch or trunk as surplus buoyancy, as there was no allowance made in connection with the other two ships, and it would be a very easy matter to make large hatches both on the single-decker and the awning-deck ship, which would further increase their surplus buoyancy if hatches or trunkways could be considered as such. He was pleased to notice that Mr. Kendall had not taken the extreme view that was taken in the article illustrating the curves of stability in *Engineering*, where it was stated that water would lie on the windward side of the trunkway, and help to bring the vessel back to her proper position; but at the same time if they had a boat with a small range of stability and little surplus buoyancy, and they were careful to load her

with cargoes that would not jeopardize her seaworthiness, she might do her work; indeed he (Mr. Sivewright) knew of a vessel with a rounded gunwale that had traded with safety for twenty-six years with a very small range indeed. It had been very broadly stated in Mr. Kendall's paper that the turret ship was an easy sea-boat. Well, it might be so, but certainly, from his experience, a flat-bottom, deep bilged ship was not so, but the loading of vessels had something to do with this. In conclusion, he congratulated Mr. Kendall upon the very excellent paper he had written, and was exceedingly pleased to see the younger members were writing papers of such practical value as they had had lately, and he hoped that the reception awarded to these papers would encourage them to further exertion.

Mr. ROBERT THOMPSON (Past-President) said he was sorry he had not been able to go so fully into this question as it deserved, and his remarks would be confined principally to the comparisons given in the paper. Mr. Kendall named the vessels he compared with the turret type "ordinary" cargo boats. Well, in his opinion, they were very ordinary cargo boats. He (Mr. Thompson) thought in that respect the comparison was not as fair as it might have been. Mr. Kendall had probably done as well as he could, but if he had had experience of some more modern vessels he would have found better results, with types less costly than those given in the paper. Of course, he took it, as Mr. Kendall said, "the main point was to raise discussion," and that was why the paper was submitted to the Institution. On page 210, fourth paragraph, he read—"On the other hand there is considerable saving effected in the cost of construction and in the reduction of tonnage, through the absence of sheer, and the simplicity of rigging, etc." As far as the simplicity of rigging was concerned, his (Mr. Thompson's) firm had built a vessel of the partial-awning-deck type which had pole masts for derricks, with triangular sails, and the height of masts made so that they would go under the bridges of the Manchester Canal. He (Mr. Thompson) thought that rig quite as simple as the turret rig. Labour and material were the principal items of cost in construction. Mr. Kendall showed a saving in material, but as to the saving of labour, he (Mr. Thompson) thought they would find the cost greater. In long poop ships the poop had formerly been rounded, but this was discarded, because the captains gave it as their experience that the round poop helped the sea up on to the deck. In consequence of this being brought forcibly home to shipbuilders the poop was made square. Of course

there was a good deal more labour in rounded sides, and the "Turr
would cost more for labour in the rounded side and harbour-deck swe
Personally, he was very much obliged to Mr. Petersen for his evide
They were not there, he hoped, simply to find fault with the "Turr
Mr. Petersen's remarks went to show that the "Turret" was all t
could be desired as a vessel. Through the kindness of Messrs. Doxf
he had seen the good workmanship upon them, and all they wanted
do was to see if there were any weak points, as compared with th
strong points. There would thus be something in the discussion t
would add to their knowledge. An advantage claimed was the reduc
of tonnage. Well, the value of a reduction in tonnage, of cou
depended entirely upon the class of ship they wanted, or the trade it
intended for. For instance, his firm had built a small boat which
carrying 600 tons and her net register was only 154 tons. They did
desire a low net register if they required to take cotton cargoes, as ow
wanted a big net register and correspondingly large capacity. Ton
was somewhat proportional with cubic capacity; while, therefore, it
desirable to have this low for heavy deadweight cargoes, it would me
reduced space for light cargoes. Mr. Petersen had told them about t
luxury of baths and mess-rooms, and the better accommodation of t
crew. No doubt it was for their benefit, but he knew these rooms ha
also been fitted to reduce the net register. Mr. Petersen probably ha
the same object in view, seeing that he had accommodation at both end
of the vessel below the main structure. Then, as to the speed of the
boats, "9 knots with 1,000 indicated horse-power." They shoul
expect more speed for that power out of the ordinary cargo boat of th
type and size discussed by Mr. Kendall. The saving of weight, h
should say, was mainly due to the reduced scantlings, and partly to th
simplicity of the outfit. Regarding Lloyd's rules, there was a differenc
in the comparison, viz., the single-deck vessel and the partial-awning
deck vessel had a depth of tank 2 inches in excess of the "Turret's.
That was adding a good deal of weight. Mr. Petersen had told the
that they had not had £10 of deck damage in all their voyages acro
the Atlantic. If they took all the bulwarks off an ordinary ship, and
cleared everything away, as in the "Turret," he thought they would
probably get the same result. He should like to ask, with respect to the
shell plating of the bottom and the engine seats, "was there any
extra strengthening in these parts, and in the cellular bottom of the ship,
as compensation for the reduction of scantlings?" He thought in these
parts the "Turret" would be weak, if anywhere. Mr. Sivewright touched

upon the question of trim. They knew perfectly well that in partial-awning-deck ships they could trim them as they liked, viz., the vessel being filled with a light cargo and on an even keel if required. This made a material difference to the statement of Mr. Kendall, who was evidently going back to the original partial-awning-deck vessels, which, in the bulk of cases, were not designed as vessels of this type, but simply had the bridge and forecastle joined together during the course of construction, and in many cases old vessels were filled in in this way. It was not fair to compare such vessels with those designed for this type, and which could load on an even keel if required. Another question he had to ask, "Was this turret ship built on Lloyd's rules, so that the basis was the same as those with which it was compared?" Then Mr. Kendall said, on page 219, "It is mainly a question of dimensions." Exactly. If he (Mr. Thompson) had been getting up this paper, he would not have given the two vessels compared the same dimensions as the "Turret." They should have been of such dimensions (for the same draught and deadweight as the "Turret") as were most suitable for the same results, which he did not think those given were. As to the statement of there being "no masts or top hamper," the remarks he had already made applied in this case, viz., that it was applicable to all vessels, turrets or otherwise. It was claimed that additional safety was obtained by doing away with sheer and adding the sheer saved as surplus buoyancy amidships. If they approved of no sheer, they were going away from the experience and results of past generations. The sheer of the old vessels, including the Dutch galliot, was essentially for comfort and dryness. If, as Mr. Petersen said, "it was not necessary for the purpose of keeping the ship dry," other people would follow altering the present type, viz., do away with sheer and add it amidships.

Mr. Kendall—Read the next paragraph.

Mr. Thompson—You get the reserve buoyancy there, just the same, don't you?

Mr. Kendall—You don't get the navigating platform.

Mr. Thompson—Mr. Petersen and Mr. Kendall agreed that the seas washed over the harbour-deck, but never came over the turret. But Mr. Petersen made the remark with respect to timber cargoes that, although the seas washed over the turrets those cargoes never moved. These were contradictory statements. For instance, he had just come

over the Atlantic, and he asked the captain of the ship how far the forward turtle-back-deck was from the water. He said 35 feet. Several times that turtle back was under water. Of course, the speed of those vessels had a good deal to do with this, but the turret's height of turtle back from the water and her speed was a fair comparison. He thought the first turret had no forecastle, no bulwarks amidships or round the stern, and that the last turret had a forecastle, midship bulwark, and round stern. If perfect before, it was not necessary to add these afterwards. If there was a cause, it would be wetness, as these erections certainly added to the cost and reduced deadweight. Mr. Kendall, when showing the load-line on the sketches of the single and partial-awning deck vessels, left it off the "Turret." The top of the after-rail of the "Turret" was 10½ feet out of the water. In the comparison ships was 12 feet in one case and 13 feet 6 inches in the other. He (Mr. Thompson) argued that, if the "Turret" was as dry as they said, must be very full at both ends, at and below the water-line, because, being without sheer and said to be dry, this could only be got by filling lines and reducing speed. In the sketches Mr. Kendall had given them the single-deck and partial-deck vessels, he had given the vessels two masts. They did not require more than two. They could, therefore, dispense with one mast, because, with the masts placed between the hatches, viz., at the forward and aft part of the ship, they got all the derrick arrangement they wanted. The cabin was placed amidships which seemed to him to be the most profitable part of the ship. They wanted moving right aft to the stern, and they would get by this alteration the main hatch much further aft, and it would practically trim right up to the stokehold bulkhead, and the No. 3 hatch could be placed to trim right up to the engine room bulkhead. The trimming of the turret aft of No. 2 and forward of No. 3 holds seemed to be excessive; further, they could not get a decent bunker hatch into the partial awning-deck comparison ship as per plan. He showed four boats on the awning-deck vessel and only three on the turret; they should fit them with four, as they might have to get out on the side where there was only one boat, which would be awkward. The cabin amidships, hood aft, and the three masts introduced were of no practical use, because they were only adding weight to the ships, and the consequent arrangements were more costly to build, and, as pointed out, affected the loading and bunkering arrangements. The number of well-deck ships afloat, and the small number of losses, had proved sufficiently that this type of ship had been a safe ship, safe to carry all kinds of cargo, and fitted for all trades

and all weathers. He had to say, in conclusion, that he did not see how the turret, or any other type of vessel, with a coefficient of ·795, could be as sea-kindly as vessels with a coefficient of ·75 or ·76.

Mr. George N. Arnison, Jun., considered Mr. Kendall was to be complimented upon the elaborate manner in which he had prepared his paper descriptive of the turret type of vessel. He had not by any means overrated the advantages derived by this important departure in the designing of cargo steamers. In fact, in one or two points at least, he had understated the improvement obtained, and this was specially noticeable in regard to the strength of the vessel as a structure. In Table A, page 223, the bending moments were assumed to be alike for both the turret-deck and part-awning-deck vessel, viz., as equal to $\frac{\text{length} \times \text{displacement}}{35} = 44{,}500$. Now, whereas this might be a fair assumption under average circumstances for the latter vessel, it was not so for the turret vessel. Mr. Kendall partially conceded this, for he said, "As a general rule a reduction would also be obtained in the bending moment of the turret vessel when subject to hogging strains, through the vessel not being so heavily weighted with cargo at the ends; but in carrying heavy deadweight cargoes this advantage would disappear to a certain extent, so that the bending moment has been assumed to be the same in each case." It was true to some extent there would be the variation he spoke of, but allowing for this, still he (Mr. Arnison) considered the strength of the turret vessel was underestimated, inasmuch as the bending moments for that vessel were overstated. The absence of sheer in the turret vessel ensured, under all circumstances, a reduced bending moment, for, in the first instance, there was considerably less weight of material in the construction of the ends of the turret vessel as compared with any ordinary vessel; and secondly, there was not the stowage space in the ends of the turret vessel that there was in vessels with sheer, so that there was with a fully laden turret vessel a still greater reduction in the bending moments. Instead of these being equal to $\frac{L \times D}{35}$ they would be, in his opinion, near to $\frac{L \times D}{45}$, if not even less. Let them then see what under such circumstances would be the relative strain on the gunwale in tons, which after all was the most important item in ordinary comparisons of the strength of vessels. Calculating from the data in Table A that $R = \frac{M}{s}$ where M = the

ıding moments, R = the moments of resistance, and s = strain in [illegible] n ıs per square inch of section, they had $\frac{44,500}{7,249} = 6,138$. Now, th[illegible]e med bending moments according to—

$$\frac{L \times D}{45} = \frac{297 \times 5,230}{45} = 34,518.$$

Substituting these figures for 44,500, they had—

$$s = \frac{M}{R} = \frac{34,518}{6,138} = 5{\cdot}62 \text{ tons per square inch,}$$

so that instead of the turret vessel having 10 per cent. less strain on the square inch of section at the gunwale it had nearly 30 per cent. less. It had been stated during the discussion that evening that the turret vessel was only a single-decked vessel with Price's patent hatches, but such a statement was very misleading. Price's or other hatches were not continuous all fore and aft, whereas the turret sides formed an integral and unbroken part of the structure, and were very important, not only from the additional structural strength thereby obtained, due to the enormous area of material at the most crucial part of the hull, viz., in the upper works at amidships, but also from the fact that the turret provided abundant feeding arrangements for bulk cargoes, liable to settle and shift. An important feature in the structural details of this new type of vessel had only been partially alluded to, viz., the hold stanchions. Instead of these being round pillars they were of double channels, forming a ⊥ section. They were not merely inefficient struts like round pillars, but were veritable struts and also ties connecting the bottom of the vessel and the upper works, or, viewing the vessel as a girder, the upper and lower flanges. Instead of having small feet they were substantially connected by means of brackets to the tank top and to the beams, the sectional area of rivet connection being nearly five times as great as the sectional area securing the ordinary hold stanchions, while, owing to the rivets being shorter, they were more likely to be efficient.

Mr. Robert Thompson said there was one thing he had omitted to say in regard to the boats. He had seen the lowering arrangement, and he thought the Messrs. Doxford were to be complimented upon the improvement made, whether applied to the ordinary ship or the turret ship. He thought it preferable to the present form of davit, and they could be put into the ordinary ship.

Mr. J. GRAVELL (Vice-President) wished simply to direct attention to the fact that if the bulwarks had been removed they would have had a canvas screen put upon the bridges for defending local places where men might be exposed to spray and gales of wind.

Mr. A. MCGLASHAN said he had read the paper on the turret type with great interest. Papers of this kind, containing an amount of information on new and experimental ships or anything else of an experimental character, in which a good deal of enterprise had been displayed, ought to be, and, he believed, were, very highly welcomed. On studying the paper one felt that all the points that could be brought out in favour of the new type of vessel had been pretty well set forth, and points which it might be expected would be rather adversely criticised had also been dealt with, and it had been shown to the satisfaction of some, perhaps, that supposed disadvantages were real advantages when viewed in a proper light. He might say he was much struck with the remarks made that evening by the managing owner of some of the turret vessels referred to in the paper; they helped the members of the Institution present to discuss the subject in a more favourable way than they could have done had they not heard the facts of the performances of these vessels spoken to by one who knew them. In the paper there had been comparisons made which were disadvantageous to the other types brought alongside of the turret type. Something of this might even be seen by the reference in the paper to the other vessels as "ordinary tramps," while the new vessel is described as "the turret vessel"—a small matter, perhaps. Formerly they knew the vessels spoken of as ordinary tramps, now they had described to them what he supposed would be the "extraordinary tramps." The peculiar and distinguishing features of the new vessel were, of course, the rounded gunwale, the narrowed deck, and the absence of sheer. He had not seen one of the vessels, but had simply studied drawings and descriptions of them. Considerable advantages were claimed for these departures from the ordinary practice, and apparently experience had so far fulfilled much that was expected of them. The rounded gunwale was an old plan that had been discarded because it was found not to answer well, and vessels without sheer had been tried at intervals, but had not been popular. The height of navigating platform, 10 feet or 11 feet, was fully equalled in the ordinary single-deck ship, the bridge of which was higher above water; and the forward part of the single-deck ship was also higher than any corresponding part in the turret vessel. He pointed out this as counter-

acting some of the favourable comparisons made for the turret ship. He was sure the turret ship had had every justice done to her, and a few points brought out in contradistinction would not be taken amiss. They were assured that the strength of the vessel was equal to, or greater than that of the vessels with which she was compared. That might be, but he thought time would show that more webs would be required in the turret vessel than were shown on the plans. The continuous structure of the turret sides and the harbour-deck was no doubt excellent; but the same material and the same continuity would probably be just as efficient if the sides were carried up and the deck extended out to something a square gunwale, as in an ordinary vessel. Of course they were told that to do so would leave too much of the sides unsupported, but that could be compensated for. Certainly without more ties than were shown in any of the sketches before them, between the two sides of the vessel, they were at once led to the conclusion that there was either too much asked for in ordinary vessels or too little provided in the turrets, and that further experience would no doubt bring out. In the matter of stability the diagrams accompanying the paper struck one with the idea that they were scientific curiosities rather than of practical value. When vessels got very much off the upright, it was very uncertain how they would behave, because of water entering by various openings, and also articles of weight shifting. They had no experience of vessels being tried at the extreme inclinations shown. He thought it must be at once admitted, that the fact of the turret ship being so quickly cut away above the water left her with less righting power than a vessel with a square gunwale and the bridge enclosed at both ends. A wood cargo such as had been spoken of in the discussion, well lashed on the harbour-deck, would probably add to the stability. In the matter of tonnage they were assured in one part of the paper that it was impossible on a small net register to get a large measurement capacity. Well, in Table A, the turret ship is stated to have a capacity for bulk cargoes of 180,200 cubic feet, with a net tonnage of 1,376 tons while the single-deck ship alongside is credited with a capacity for bulk cargoes of only 175,226 cubic feet, and at the same time is said to have a net register of 1,495 tons. What he would say in regard to that was either a good deal had been left out in computing the capacity of the single-deck ship, perhaps some bunkers or other closed in space were omitted, or else the measurements of tonnage and internal capacity had not been taken under the same conditions, apart, of course, from the question of type. Of course, it would be easy to reduce the tonn

in the single-deck vessel by placing the crew down in a sunk forecastle. Coming to the matter of scantlings, the single-deck ship given for comparison was not such as were being built now. He thought that would account for a great deal of the difference in weight and results generally; and one might be allowed to say, in conclusion, that if the facts relating to the different vessels were correctly stated in the paper and the comparison as fair as could be made, there was either something wrong in the method of applying the tonnage measurements between one type and another, or some difference in computing the internal capacities; and probably the assigning of freeboards required to be closely looked into. The scantlings in relation to transverse strength as already indicated might, to his mind, be reconsidered with advantage. He thought the new type should be viewed with favour in some respects, especially in having a continuous structure in the upper part; but he thought the fact of having a narrow deck to get about on, either in harbour or at sea, and notwithstanding the assurance they had had of boats being easily got out, was against it. He thought they would prefer square sides and the decks carried out, at least in way of the boats, so that in emergency there might be some chance for men to get to the boats. He spoke not so much in antagonism to the new type as in the way of extending comparison with the other types.

Mr. F. Yeoman said he did not wish to underrate the turret ship. Like Mr. McGlashan, he would welcome any improvement; but he thought he gauged from the paper and from the remarks of Capt. Petersen that the principal thing aimed at in the building of this ship was how much she would carry on how small a registered tonnage. In the case of both shipbuilder and shipowner the aim was alike to-day, and it had long prevailed. Arising thereout he was thrown back to a consideration of where they had come from upon this phase of the subject. Capt. Petersen laid great stress upon the "commercial points," and with him, naturally, as a shipowner, it was commercial points from beginning to end, and these were what the steamship builder had got to satisfy. He could not help remembering that in years gone by they had had other types of ships in which they then thought they had both power and safety. They would remember between 1870 and 1880 the narrow type of ship, and she had "commercial points." The small well-decked ship that preceded her was persecuted, and so the naval architect, from a commercial standpoint, built the narrow double-decked type of ship. They had since had to lament the loss of many such a

l it was well known that they were now virtually a thing past. Then came the larger well-deck ship, which had their credit all through. To go back to the year 1882, forcibly reminded at this time of depression, that shipowners built steamers capable of carrying about 2,350 tons, upon the ince up to that date. Unfortunately, the power above them was a tly autocratic power, and they came down and said, "This ship is it to carry 2,350 tons, you must take, say, 110 tons to 170 tons and it had to be taken out, and the shipowner had no remedy. He theory and the law of the country against him at that time, and it s no use appealing to any court in the country upon that particular ip and such carrying. The freeboard of that ship was about 1 foot 0 inches, but she was dubbed "unseaworthy" unless she had 2 feet inches to 2 feet 10 inches freeboard in summer or winter. Where were they now? After many years of battle upon the freeboard question perhaps this vessel was conceded a 1 foot 11 inches (summer) and 2 feet 2 inches (winter) freeboard, but which penalising she was unable to carry and live. This penalty represented a fair interest on capital invested. But the irony of the position was that the only way out of the difficulty was to sell such a vessel to a foreigner, who would immediately put into her the extra quantity of cargo the British owner was not allowed to load. Moreover, a common freeboard of a similar 2,800 tons new steamer to-day is 1 foot 6½ inches, the new vessel having been given concessions, the result of the clean reputation of the older type, but of which they were not allowed to reap the advantage.

A MEMBER—What has this to do with the turret-deck ship under discussion?

Mr. YEOMAN—This, Mr. President, that tonnage for tonnage and ship for ship, his idea was that if they gave the old ship the same freeboard and other concessions given the new ship she would still live and maintain her good character, as to which they need have no question at all. Capt. Petersen had pointed to the fact that the "Turret" had had no deck damage in two years. Representing 258 steamers of the Hartlepools Shipowners' Society, he had been able to tell the Board of Trade the other day that there was no record of a local well-decked steamer having failed consequent upon her grain loading since the Carriage of Grain Act came into operation, fifteen years ago—a record [illegible] might fairly be proud. All he would say in regard to

sheer was that he thought any sailor with an eye for a ship liked a bit of sheer, and he hoped the day was far distant when they would have straight ships without sheer. In regard to the purchasing of the older vessels by the foreigners, he might mention that three local steamers had recently been sold in fourteen days, and at that rate therefore it would only take seventeen months to get rid of a fleet of one hundred such locally-owned vessels. He held that if the same consideration was shown the older type of vessel, and concessions made by the British authorities, they would still live, and be a credit to all concerned.

Mr. C. D. Doxford, on being called upon, said to the President that he would hardly be able to reply to all the criticisms in ten minutes.

Mr. Fothergill—It lies with the reader of the paper to reply to the discussion.

Mr. Doxford explained that he should rather have said "Unable to explain the various points raised against the turrets."

The President asked Mr. Doxford to go on.

Mr. Doxford, proceeding, remarked that he felt when he came into the hall that he was entering into the very heart of the opposition to the turret vessels. There was no doubt that Hartlepool was the place of the well-deck and the partial-awning-deck vessels. They had proved admirable vessels, but from the criticisms made upon Mr. Kendall's paper various points had arisen in regard to the turret type that he thought he was entitled to review. One of the great points raised against these vessels was the want of sheer. Now, it was a matter entirely of preference whether they put sheer or not. He (Mr. Doxford) certainly preferred them without sheer. They could get the necessary height of platform without it, and therefore it was quite unnecessary. He would like to dispel the illusions which appeared to exist regarding the height of the turret vessels above water, especially as described by Capt. Nicholson at the last meeting, and to do this he would show them a diagram of the "Turret Bay" and "Manar" (see Plate LXV). He hoped they could all see the diagram; he (Mr. Doxford) had made it on the basis of Capt. Nicholson's remarks, and from information taken from *Lloyd's Register*.

Capt. NICHOLSON—The vessel was not mentioned or touched upo and he thought any comparison most unfair. He protested against M Doxford touching upon a vessel not mentioned.

The PRESIDENT—Let us hear Mr. Doxford.

Capt. NICHOLSON—In all fairness he must ask him not to disc a vessel not brought forward.

Mr. DOXFORD said he thought Capt. Nicholson was so proud of his ve that he would have been pleased to see her alongside of a turret. H ever, in deference to Capt. Nicholson, he would remove the name, and diagram then represented a partial-awning-deck vessel, particulars of wh are recorded in Lloyd's, and which information is public proper He felt extremely obliged to Mr. Thompson for the complimenta remarks he had made. His criticism was given in all fairness. And, Mr. Thompson said, "they wanted to find the weak points and mar them." Well, he did not think Mr. Thompson had found one in the turrets. But he would point out and "mark" the weak points in the partial-awning-decker. There they are (pointing to the two breaks in the deck-line on the diagram). Now, why design a vessel with these weak points, and then go and stick on patches to make it up? Surely it would be better to build their bridge straight away and avoid these weaknesses. One of the important questions raised, and which appeared to exercise the critics, was this question of tonnage. Everybody hummed and hawed about it; some said there was nothing in it; but everybody fenced round the question. There must be something, or everybody would not get so much annoyed.

Mr. SIVEWRIGHT—You have reduced the tonnage.

Mr. DOXFORD—They had not reduced the tonnage. They had left the tonnage alone and increased the commercial efficiency of the vessel. In this case of the partial-awning-decker, with all due respect to Mr. Nicholson, he would leave the name out.

Capt. NICHOLSON—That did not at all represent the vessel.

Mr. DOXFORD—Yes, it did. He would take the figures directly. Here was a partial-awning-decker.

Mr. SIVEWRIGHT—Not a Hartlepool partial-awning-decker.

Mr. DOXFORD—No. The Hartlepools deny their offspring. If there had been no question made of the name she might not have been a Hartlepool type but a Tyne type. She was a partial-awning-decker, however, such as any builder could build, laden with all her weaknesses. She was a vessel given in Lloyd's as having a freeboard of 8 feet 7 inches measured to the partial-awning-deck. That, first of all, was a bit of a fallacy, for it dropped suddenly there (pointing to the break), and they would say she had 7 feet sheer at the fore end, and they would say 12 inches round of beam. If they added these together it was equal to about 16 feet 7 inches above water at the stem, as shown by the dotted line, against, it was said, 4 feet 8½ inches in the "Turret Bay." Now, what were the facts regarding the height of the turrets? The assigned freeboard amidships of the "Turret Bay" was 10 feet 6¾ inches. The vessel had no sheer, but had a top-gallant forecastle 7 feet high. Therefore the height at the fore end of the vessel was 17 feet 6¾ inches, against the partial-awning-decker's 16 feet 7 inches, and as she was a deeper loading vessel—loading to a draught of 20 feet 10 inches, against the "Turret Bay's" 19 feet 8½ inches—it was clear that she had a worse navigating platform than the "Turret Bay," and this was illustrated by the "objectionable" diagram. Then there was a very important insinuation made about the question of classing with Lloyd's. Reference was made, in the list Mr. Kendall gave, of the vessels classed in Veritas. It should be also in the British Corporation, and one vessel was classed in Lloyd's. The question was asked, "What was the difference in the scantlings?" Now, he dared say, some of them would be surprised, but anyone might call and see the figures. The "Bencliffe" and "Turret Bay," sister vessels, had a difference of 19 tons, and 15 tons of this lay in the "Bencliffe" having an iron centre bulkhead, which was a special arrangement in that vessel, leaving a margin of about 4 tons for Lloyd's rules, and those 4 tons were entirely thrown away in vertical web frames, which simply obstructed the stowage of cargo and were quite unnecessary.

Mr. SIVEWRIGHT.—Had they the same freeboard?

Mr. DOXFORD—The same freeboard. There was no question of the freeboard. It had been arranged between the authorities; they had all met and agreed upon what was the correct system for freeboard for the ships. Capt. Watson's remarks regarding the vessel's evident desire, as shown by the diagram, to sit at about 30 degs. inclination either side

were pure chaff or ignorance. "Thirty degrees of inclination!" Anybody that knew anything about a stability curve knew that that was not the reading of Mr. Kendall's diagram. He hoped Capt. Watson knew a little more about stability than that. Given two vessels with the same form under water, and the same centre of gravity, and the stability would be the same, and the under-water portion of the turrets was the same as ordinary vessels. Really it was astonishing to him that the great majority of these criticisms had resolved themselves into a lot of chaff. Mr. Sivewright made a point about putting the engines amidships and improving the design. Now, they had not changed the engine amidships to improve the design, nor had they lowered the working capacity of the vessel by doing so. The measurement capacity of the vessel with engines aft and engines amidships was the same—it was a matter of pure choice for the owner. The stowage was, of course, best with engines aft. If the vessel was for voyages up to say twelve or fourteen days they put the engines aft, if they were going to exceed that they put them amidships. Judging Mr. Sivewright from the sketch he had made, he seemed to be awfully down upon these ships, but he was far astray when he said they were simply single-deck vessels with Price's patent hatchways way. What he looked upon as Price's patent hatchway was, in these vessels, the main structure, and carried the main sheer and stringer at the upper part, and the hatches were above that again. It had also been pointed out that the rounded gunwale would not do, and no doubt a round gunwale to a flat deck would not do, but they had built up the main structure of the vessel inboard to return the waves as they came on, and the deck was above this and kept free from all heavy water, and this was not fancy but fact, and proved by the working of the vessels. The question of costs had also been touched upon by Mr. Sivewright. He was not going to tell them much about that, they were quite satisfied with it. Mr. Thompson had mentioned the two masts instead of three. To-day the first object of a mast was to serve as a crane post to work the derricks. And if they only required two, do not put three. They could get all necessary sail on without making them as high as they used to be. They had never said these were the only ships they could do that with, and he was gratified to see other builders were adopting the idea.

Mr. Thompson—What he complained of was the comparison made with them.

Mr. DOXFORD next referred to Mr. Thompson's remarks *re* horse-power and speed. Mr. Kendall evidently took the horse-power from the Register; given the same dimensions and coefficient the horse-power would be the same as in any other vessel. There were sundry odds and ends in the criticisms of the plans, such as that there were only three boats shown—that really must be Mr. Kendall's fault, but it had nothing to do with the type. Mr. McGlashan referred to the want of ties (pointing to the harbour-deck). In this case he would like to draw their attention to an important feature of comparison, as to the strength of the vessels in way of wide space beams or hatches. The section of material in the ordinary vessel was thus, and gave a very inefficient girder against lateral straining, as the neutral axis was close to the side of the vessel, and caused excessive strains on hatch openings. But in the turret the section of material was not only heavier but placed so that the neutral axis was about midway between the side and the hatch, giving an efficient girder against lateral strains from either side, and would allow of much wider spaced beams and larger hatches than they could afford to go to in ordinary vessels. The question of spare buoyancy had been touched upon by more than one speaker. He thought this had been met by what had been already said and by the diagram, although on the forward shoulders of the turrets there was no doubt less buoyancy than on a partial-awning-decker; but the turret had considerably more than the flush-deck types, and they had been proved to have plenty. He had a great deal of correspondence from all the vessels of the turret type now afloat, and he proposed to give them extracts of letters from each of the ships to show what they were really doing. Mr. Doxford was proceeding to read from the letters, when

Mr. FOTHERGILL proposed that, instead of Mr. Doxford being hurried through, he should continue the discussion at the next meeting.

The PRESIDENT and Mr. DOXFORD agreed to the adjournment of the discussion.

Mr. WATSON wished to explain to Mr. Doxford that he made no insinuation. He simply referred to what was in the paper, and asked a question with regard to Lloyd's.

EXTRACTS FROM LETTERS ALLUDED TO BY MR. C. D. DOXFORD.

In a letter dated August 18th, 1894, Capt. Taylor, of the S.S. "Turret," writes :—

I have now been in the "Turret" since January, 1893, and have experienced some very heavy gales when she has been deep loaded, and I must say her behaviour was wonderful. The seas do not seem to encumber her as they do an ordinary type of vessel. I have seen her in very severe weather when a very high sea was abeam, and looking at them you would think they were going to sweep her fore and aft. She simply rises bodily to them, flooding the lower decks, and they then fall again. When the seas strike the lower deck or turret side they rebound and the lower deck is instantly cleared of water.

With the sea on the bows she simply ships water on the lower decks abreast the cabins, and with the sea ahead or aft she ships water on the lower decks in large quantities, but the least motion of the vessel clears them instantly, and when steaming against a very heavy high head sea we took no water over the turret-deck at all.

During all my experience in all weathers with her I have never seen a true sea shipped on the turret-deck.

Capt. Danielson, of the S.S. "Turret Age," writing on October 26th, 1894, says :—

I have more confidence than ever in the turrets as safe and good sea-boats. I may mention that we have not once had any water in the turret-deck, except spray flying over the hood when going into a head sea.

Capt. Klitgaard, of the S.S. "Turret Bay," writing in June, 1894, says :—

I was never in a better ship than this as a sea-boat.

Capt. Donovan, of the S.S. "Bencliffe," writing to Messrs. Horsley & Son, his owners, in June, 1894, says :—

She is very handy, and behaves well at sea. We never had the hatches battened down either fore or aft. She rolls very steadily. We have not had a heavy gale, but we have had some bad weather, and at times very heavy seas. She takes no water on the turret-deck. She does not seem to stop against a head sea as ordinary vessels do, and she steams very well.

Capt. Boyd, of the S.S. "Turret Bell," writing in March, 1895, from Las Palmas, says :—

Coming from the Plate we struck a strong breeze and heavy head seas, but the vessel behaved gallantly, taking no seas aboard, but lots of spray. We have had a rough passage, and have had to steam against strong head winds and seas the whole way from the Plate.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

ELEVENTH SESSION, 1894-95.

PROCEEDINGS.

EIGHTH GENERAL MEETING OF THE SESSION, HELD IN THE LECTURE HALL OF THE SUNDERLAND LITERARY SOCIETY, SUNDERLAND, ON WEDNESDAY EVENING, APRIL 24TH, 1895.

ROBERT THOMPSON, ESQ., J.P., PAST-PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, held at West Hartlepool, on April 6th, 1895, which were approved by the members present, and signed by the Past-President.

The PAST-PRESIDENT took occasion to explain the regrettable absence of the President on account of illness in his family.

The discussion on Mr. S. O. Kendall's paper on "Turret-Deck Cargo Steamers" was resumed and again adjourned.

Mr. G. H. BAINES read a paper on "The Metric System of Weights and Measures: a Plea for its Adoption in the United Kingdom."

ADJOURNED DISCUSSION ON MR. S. O. KENDALL'S PAPER ON "TURRET-DECK CARGO STEAMERS."

Mr. C. D. DOXFORD said those who were present at the Hartlepool meeting would remember the point at which this discussion was adjourned, and most of them would remember why the name was taken off the diagram of the partial-awning-deck vessel. He might as well explain the reason, perhaps, to those who were not at Hartlepool. The name of the vessel was given to show that the dotted lines were representing an actual steamer, not an imaginary one—a vessel which they could take as a typical partial-awning-decker—a vessel which had been set in competition with those they were now building. However, the owner of the vessel (Capt. Nicholson), who was, perhaps, their most severe critic, objected to its appearing. The name of the vessel was not mentioned by him, therefore it was now nameless, but still a partial-awning-decker. The point he wished to press upon the meeting was that the dotted line (see Plate LXV.) showed a partial-awning-decker recently built, with which they were perfectly entitled to compare the turret vessels, and it was put up to show that the height of the platform—the great crime of the turrets—was actually greater in the fore end of the vessel than the partial-awning-decker. They were slightly deficient here, but elsewhere were in excess. It was also necessary to have a name to this vessel, because he wished to work out the particulars, and compare them with a turret vessel they had built of almost the same dimensions. The comparisons and particulars he would give further on. There was a good deal of criticism upon various small items which, he confessed, they could ignore; the great question seemed to lie in the capacity. They seemed to be charged that they could only build these vessels as deadweight boats, and could not make them measurement vessels. They first had Capt. Watson, who said that they had sacrificed everything—capacity, sheer, appearance, everything—in order to get a low net register. Now, that was a thing they had not done. Mr. Sivewright referred to the subject of the small net register, and said this could easily be done when they simply wanted a deadweight boat. He referred to Mr. Kendall's figures, and pointed out that the turret vessel only averaged 124 cubic feet per net register, whereas he (Mr. Sivewright) of Hartlepool had built vessels of 130 cubic feet, with the marvellous amount of 268 tons bunkers. Now, he (Mr. Doxford) had no doubt that 130 cubic feet was inclusive of the

peaks and every available space in which they could possibly put cargo. Then Mr. McGlashan referred to the same question, and pointed out that probably Mr. Kendall, in his particulars of the partial-awning-deck ship, had forgotten to measure in the peaks. Well, he (Mr. Doxford) knew the particulars of the turret vessels did not include the peaks, but simply the holds actually and always used for cargo. Then Capt. Nicholson, at the first meeting, speaking of the capacity, remarked that the ship was a thorough waster, that it had no capacity at all, and that they could not get her down to the load-line with a coal cargo. Mr. Yeoman, they all knew as a most experienced shipowner, pointed out that well-deck vessels had actually been sold away from the English flag because the freeboard had been increased, reducing the deadweight, but not affecting the capacity at all, but increasing the measurement capacity in regard to the deadweight to be carried, and yet those vessels had been sold away from the flag, three ships a fortnight, and that in seventeen months from now they would not have a well-deck vessel in England. Why? Because they were no longer deadweight boats. Here, on the one hand, they had gentlemen claiming that the turret vessels were no use because they were purely deadweight boats, while, on the other hand, they had an experienced shipowner complaining that a certain type of vessel had had to be sold from the English flag because she was no longer a deadweight vessel but a measurement vessel. He regretted he had to speak so fully upon this question of the measurement, but it was, in his view, the most important subject with which he had to deal. There had certainly been too much taken for granted on this question of the turret ships being deadweight vessels. The vessels they had turned out so far had been deliberately designed with quantities of about 50 or 51 cubic feet per ton deadweight cargo, simply for the reason that the owners were satisfied with that, and that it would meet the general requirements of ordinary trade. If they put in a capacity of 55 or 60 cubic feet, then the vessel was handicapped if carrying a denser cargo; and if they wanted a vessel to go into any trade, clearly they should average out the requirements, and he found their average ran to 50 and 51 cubic feet. However, if an owner was not satisfied with 50 cubic feet, there was not the slightest difficulty in designing a turret vessel with 60 cubic feet to the ton deadweight. In connection with this point, he might say they had now in hand turret steamers which had a grain capacity in the holds, without interfering with the peak, where they were not supposed to carry cargo, of 57 cubic feet per ton deadweight in the holds clear, and that particular vessel had 340 tons of bunkers against Mr. Sivewright's 268 tons,

The bale capacity was no less than 55·6 cubic feet per ton deadweight. He thought those figures compared very favourably with what Mr. Sivewright said he could do with a partial-awning-deck ship. The point again came in on the relation of the cubical contents of the vessel to the net register, and there was no doubt that that was the basis of the commercial efficiency of a steamer. If they could increase their capacity without increasing their tonnage, and still avoid open deck erections, they had got a better ship. In the turret boats they had undoubtedly a bigger deadweight capacity than could possibly be got in the ordinary types of similar dimension, and that handicapped a vessel in getting measurements per ton deadweight. But surely an increase of deadweight capacity was not a fault. The relation of the cubical contents for grain, excluding peaks—he wanted to be very particular upon that point, for so many people would include the peaks for capacity—was as follows:—The grain quantity was 135 cubic feet per ton net register, and the bale capacity 131 cubic feet to the ton net register against Mr. Sivewright's champion ship of 130 cubic feet grain space, including peaks. Then Capt. Nicholson referred to the same question, and said that the vessels would not load down with coal. It would be an extraordinary ship that would not load coal cargo, unless they had got coal altogether different from the common. But against the imagination of Capt. Nicholson they had recently, within the last few weeks, sent to sea three of those vessels from this district, loaded with coal and coke. In the case of the 3,050 tons vessel she loaded 3,050 tons deadweight, and 250 tons of this was coke, and yet the vessel was down to its load-line, and the holds were not full. Now, then, they came to the actual comparison of the turret ship which had been sent to sea, and this nameless partial-awning-decker. Here they found the dimensions very similar—length of the partial-awning-decker, 293 feet; turret, 297 feet; the beam was the same; the depth of the partial-awning-decker was 22½ feet, and in the turret 24·1 feet. The gross register of the former 2,562 against 2,211 tons, and the net register 1,638 against their 1,375 tons. Now, the deadweight capacity, if the coefficient of both were the same, ·792, would be 3,808 tons in the partial-awning-decker and 3,838 tons in the turret. The load draught was shown to be, in the former, 20 feet 10 inches against 19 feet 8½ inches in the turret. Taking the permanent bunkers as being the same, 278 tons, they had the cargo in the partial-awning-decker as 3,530 tons against 3,560 tons in the turret. He might say that the grain capacity of this wonderful partial-awning-deck ship, excluding peaks for comparison, was 191,810 cubic feet, that of the turret 180,250 cubic feet. The cubic feet per net register

117·1 against 131·5 in the turret, and the cubic feet per t[illegible]on ırgo 54 against 50·6. A smaller capacity and larger deadweight[illegible] hat was the point in the turret type everyone had got hold of—a[illegible]nd .t seemed to be taken for granted that they could not do anyth[illegible]ng else. Now, they could; but even taking those particulars as they sto[illegible]od, the relation of the net register was only 117 to their 131. If they t[illegible]ok that as the measurement of the commercial efficiency of the vessel, [illegible]he thought their vessel must beat the other. Of course, he had had [illegible] to assume the coefficient of the partial-awning-deck ship, because he did [illegible]ot know what coefficient she had. He did see, by reference to one of [illegible]he papers, that this very vessel instead of carrying 3,800 tons was repo[illegible]ed to carry 3,900 tons; if that was the case, according to the argument [illegible]on the capacities, she was a worse ship if she carried 3,900 than if she carr[illegible]ed 3,800 tons, but she was not any more than theirs when she carried de[illegible]y-weight. He hoped he had put this distinctly enough to dispossess ever[illegible]ity one's mind of the idea that they could not make a turret ship a capaci[illegible]ey ship. They could make them 60 cubic feet to the ton, provided the[illegible] if knew the owner wished it before the vessel was designed. Of course, i[illegible]he she was laid down they could not change her into a capacity boat. Th[illegible]in next note he took was one which he approached with some delicacy, seein[illegible]u their critic was now sitting as their Chairman, but it was a point he coul[illegible]ti not allow to pass without challenge, because it was in that most influentia[illegible] paper, *The Shipping Gazette*, and stood under the name of Mr. Robert[illegible] Thompson, of Sunderland. It was a point he had certainly felt very much[illegible] Capt. Petersen happened to refer to the fittings of the vessels, and sai[illegible] that they had not sustained £10 worth of damage on deck. Mr. Thomp[illegible]son said he supposed there was not £10 worth on the deck to damage[illegible] He had been taken to task for saying some of their critics had fallen into chaffing them. He thought that was a generous view to take, for if this was not chaff it was something worse. Now, imagine a vessel with only £10 worth of stuff on deck, and that paragraph would be read by gentlemen all over the world, who would say:—"Why, here is a vessel built by Doxford, of Sunderland, and not £10 worth on the ship!"

Mr. Fothergill—They would not know much about a ship, then!

Mr. Doxford—He could assure them, if it was necessary to do so, that these vessels went to sea with all the fittings on deck as usual in the ordinary vessel—all the winches, all the steam pipes, exhaust pipes, ventilators, ropes, derrick, and so forth; the only difference was this,

they were very carefully placed, and did not obstruct the view very much. When they went on board the turret vessel there was not much to be seen, but everything was there. If Mr. Thompson or any other shipbuilder could show him how to put five winches, steam and exhaust pipes, ventilators, steam capstans, bollards, fairleads, wire reels, skylights, castings, etc., on deck for £10, he would willingly begin his apprenticeship again and give a very handsome sum for his indentures. There was another matter touched upon by Mr. Thompson, that of the special stiffening in the bottom of the vessel—these wonderful vessels not built according to Lloyd's rules, or supposed not to be—"special compensation in the way of the engines because in their experience they had broken bedplates"——

Mr. THOMPSON—No, never.

Mr. DOXFORD (reading printed report)—Oh, he had heard of them.

Mr. THOMPSON—Yes; that's right.

Mr. DOXFORD was very glad Mr. Thompson had not had that experience. He hoped nobody on the Wear had. They certainly had not. The double bottom of the vessels were built in the ordinary way, with the solid floor on every frame, extending from the keelson to the tank side, with double reverse bars under the engines and boilers, all as usual, and certainly, as far as he (Mr. Doxford) was aware, they never had any sign of shaking engines or broken bedplates. Then they had the question of the boat gear. Capt. Nicholson fell foul of that, and Capt. Watson said it was simply impossible to put out the boats from these vessels at sea, and if their boats were out, he asked, how were they going to get into them? No doubt, Capt. Watson would not have said what he did if he had taken the trouble to go to Pallion and see the gear in operation, for he described it as having two keys to remove from the davits, two pins to remove from the chocks, and a whole lot of things, requiring four men. Now, that was not the case. In the ordinary vessel they were thoroughly accustomed to the difficulty of getting the boats out, and a vessel five or six years old would defy anybody probably to get them out at all; but taking a liberal view it would probably take all hands to have one of these boats slung out in a quarter of an hour. How were they to get into them in a rough sea? They did not deal with that, but they must get into them down the falls or somehow. Now, in the gear they had

adopted to get the boats out of the ships, they could in the roughest launch one of these boats in two minutes with two men, for it required one man at each fall to retain the boat from running down, the officer in charge of the operation had only to take the keys and the whole thing was lowered instantaneously. There was mechanism about it, it was worked by gravity; as soon as they took keys out of the chocks and davits the weight of the boat was suspend and they had the natural force of gravity to carry the whole outboar It could be allowed to run at full speed, but that would be much t quickly to be safe. As far as the derrick was concerned, it would simp stop when it came to the end of the suspension ropes. And then the had the experience of Capt. Petersen, who put them out in a rough sea.

Mr. MIDDLEMASS—There is one point occurs to me. If there is n difficulty in putting off, how about getting on to the ship?

Mr. DOXFORD said, that from the experience they had had, very much less difficulty than on an ordinary ship. They had had the experience o a pilot when he went out to meet one of these vessels in the British Channel in a heavy gale of wind. His statement was that if it had been an ordinary vessel he would not have boarded her. It was astonishing the notion about this ship. There was one left Sunderland the previou day on a trial trip, and the prediction of some people was that those o board would have to go away with her. Why, they simply stepped o from the deck to the tug. There was no difficulty—it was purel imaginary. He had to express his gratification to Mr. Kendall on th success of his paper, and thanked them very much for the interest shown in the remarks which he had made.

Mr. T. MIDDLEMASS said he had read Mr. Kendall's paper, and he also had the pleasure of hearing the discussion at Hartlepool, from which he gathered that the comparison between the part-awning-decker and the turret had at the first reading been well gone into, he would therefore only make one or two remarks before turning to the single-decked ship. With regard to Mr. Doxford's comparison of height of navigating platform. The sketch gave the part-awning-decker a height forward of 36 feet as against a height to turret-deck at the stem of 29 feet 9 inches. Mr. Doxford, however, added the hood to this, giving a height of 35 feet 9 inches. As navigating platforms there could, he thought, be no comparison between the two. In the part-awning-decker it was

structurally part of the ship, in the turret it was an open-ended hood, and, if the sketch was accurate, not used as a navigating platform at all. The great camber of the top (considering its breadth) would also, he thought, prevent its being used for a look-out. The paper stated an allowance in the freeboard was made for this hood, which, one would think, must be very small. The profile showed the part-awning-deck as a wooden one. If this was so, he thought the assumed freeboard was more favourable than would be assigned; if, on the other hand, the deck was, as usual, an iron one, the wood sheathing was certainly unnecessary, and was only adding to the light weight, and *pro rata*, deducting from the deadweight. There were other points which he would not go into, merely remarking that the break of quarter-deck was hardly in accordance with section 45 of Lloyd's present rules, and that a third mast was not required. He would now turn to the single-decker, which he could deal with in more detail. To begin with, the type chosen was a very poor one to compare with an up-to-date turret, for he did not suppose there was one steamer of this particular type, erections, and of something like the same size, building on this coast, for no particular trade but to enter into competition in the open market with turrets and part-awning-deckers. It was thirteen years since the firm with which he was connected built one of that type, and in that case it was for a particular trade. The tables of different steamers built by Messrs. J. L. Thompson & Sons, which the Past-President (Mr. R. Thompson) gave in connection with his inaugural address at the opening of the 1892-93 session, gave the last steamer of this type as built in 1882, and the largest of them only carried about 2,800 tons. But even supposing that type of steamer was being built, how had it been treated in the plans and table given? Take the section: it showed a moulding on the upper edge of the sheerstrake, which might have been put on in 1882, but was not considered necessary now the turret had no mouldings. Again, he saw none of the flanging of plates or the use of large sections of iron, which evidently were used in the turret, and which, he took it, could be no infringement of any patent. Take another point: the frames in the turret were 6½ inches deep and of bulb angle. In the single-decker they were composed of frame and reverse frame, and were 5½ inches wide: this gave the turret an advantage of 2 inches in the tonnage for the depth of side. It might, however, be said in this connection that the single-decker had a tank 2 inches deeper than the turret, which would counterbalance this. This he failed to see. If the ship had to carry the extra weight which 2 inches on the depth of

tank would give, there should be an advantage somewhere, and why not in the tonnage? He took it they were comparing types of steamers, not one steamer built with every advantage that the use of large sections of iron, and every appliance for flanging and working heavy bars and plates, and another steamer, such as a builder with only ordinary appliances and plant would have turned out in the year 1880. If it was an advantage to the turret to flange floors, stringers, etc., and to use large sections of iron, put the single-decker on the same footing. They were comparing types, not constructional details. Take the profile: the turret requires two masts aft, and this disadvantage the single-decker, for no reason, was saddled with. There was also a steering house aft, which, if necessary at all, was 3 feet too long. These things struck him very forcibly, as the turret profile and section did not contain any unnecessary weight of any kind. He would like to ask Mr. Kendall, in connection with the scantlings of the single-decker, whether the section had been approved by Lloyd's, particularly the spacing of hold beams and web frames? He turn to Table A, page 223. The under-deck tonnage, was, he thought, too high, considering the rise of the cellular tanks towards the ends of the ship. He then called attention to a drawing he had prepared of a single-deck steamer, which he desired to compare with Mr. Kendall's turret steamer.

The PAST-PRESIDENT here ruled Mr. Middlemass was hardly in order in bringing this forward, and that there was not time to take up the design.

Mr. J. R. FOTHERGILL said the greater part of the criticism on Kendall's paper had been offered by shipbuilders, and much had been said from what might be termed a scientific consideration of the features which the turret type of steamer introduced. There was no doubt the discussion had been valuable and interesting, but he ventured to think there were features of consideration from a shipowner's standpoint which he might with advantage refer to. When a shipowner decides to build a new steamer, and makes up his mind as to the deadweight tonnage, he approaches the shipbuilder as to costs, and requires the following information for comparison as to the commercial value or earning power of the vessel:—The cubic capacity measurement for case cargo, and the draught and registered tonnage for the deadweight carried, assuming the speed and consumption to be as usual. It was relative to these particulars that he felt obliged to corroborate the opinion expressed by several speakers that

Mr. Kendall had not been at all happy in his selection of the particular steamers given in comparison with the turret steamer. He had carefully gone into the question since their last meeting, and found that there was more than one steamer afloat which had cubic capacity measurement and draught for deadweight carried equal to the turret steamer, but the turret showed a decrease in registered tonnage. If Mr. Kendall had taken an up-to-date partial-awning-deck steamer, the same as he had taken the up-to-date turret, he would have found a very different result, and one not nearly so favourable to the turret. Undoubtedly the turret had a low registered tonnage, and although the great advantage of this was mostly felt in trading through the Suez Canal, yet in other trades there was a small saving which, particularly in these times, was not to be ignored. Some few years ago a strong feeling existed that it was desirable a steamer should have a high register tonnage, as it offered considerable advantage when a vessel was chartered by the register ton, but at the present day charterers were wide-awake, and required to know the cubic capacity they would get per ton register, and on that the freight was based, and therefore there was no advantage to be gained by high register tonnage, and thus for an all-round general cargo steamer the lower the register tonnage for deadweight carried the greater the economy. As to the sea-going qualities of the turret type, he was of the opinion that those who had had sea experience, and he might say that he was not without experience, must admit height of platform was a most important feature in the good sea qualities and comfort of a steamer. He could not agree with those who spoke of the turret-deck as the navigating deck. This steamer was fitted with a navigating bridge the same as all cargo steamers. The turret-deck was what he might call the "working-deck," a safe height of platform that the crew could with comfort and ease get from one end to the other in any weather. Was not that of vital importance? It could not be always accomplished in the partial-awning-decker without considerable risk, coupled with a good wetting. He remembered speaking in that same room some seven or eight years ago, when he predicted it was only a question of time before the well-deck would be filled in from forecastle to bridge to obtain reduction in freeboard, and when that was accomplished they would have removed the "half-tide rock" from the front of the bridge to the after-deck. This was now an accomplished fact, as all those who had any experience of the modern partial-awning-decker well knew; in fact, in several steamers of this type, they had found it necessary to run a plank gangway to the hatches for convenience in getting aft. Compare this with the height of platform the turret-

deck gave, and he thought the great advantage must be paten
Comment had been made that the turret-deck was so narrow
useless as a working-deck. Of course it was much narrower t
deck of an ordinary steamer, but he was afraid those who had
mented had not had the advantage of inspecting these steam
might say, by the courtesy of Messrs. Doxford, he had been priv
examine more than one of the turrets, and he certainly found am
for all requirements on the turret-deck. Much had been said a
round of side, and that it had been condemned years ago as a mi
that it facilitated the taking of water on board. He would ende
show there was no comparison as to the round of side in an
steamer and that of the turret. He was not speaking from a ship
consideration, but purely as a question of taking water on boa
illustrate his point, Mr. Fothergill depicted by sketches on the bl
(see Figs. 1 and 2, Plate LXVI.) an ordinary steamer with
side and a turret steamer, in both cases heeling over and shippin
In the ordinary steamer it was plain as soon as the sea turned t
of the side it rushed across the deck with considerable
frequently carrying everything before it, whereas in the turre
carried up and thrown off by the formation of the turret, as shov
sketch. As to the general seaworthiness of the turret type, he c
say that he felt sure those who heard Capt. Petersen's manly and
forward description of the voyage he made could not do other
believe the turret steamer to be as sound and safe a sea-boat as e
the ocean. There was another question he should like to see
ventilated, and that was relative to sheer. As an engineer h
hesitated to place his opinion against the expressed opinic
nautical gentlemen who had made such a point of sheer.
appeared, if they had height of platform, it was equivale
and he failed to see that sheer was other than height of
bow and stern, and certainly the turret had this. He
appearance that sheer gave to a ship possibly led to a misco
its value, but he would like to hear Mr. Kendall's opinio
one other valuable feature in the turret he would like to re
was the continuity from end to end of the upper st
undoubtedly gave strength, and tied the whole stru
effectively, particularly as compared with the partial-aw
which type of ship they had experienced such frequent
after-end of the bridge. He was not quite sure whether
to the £10 damage, but he did not understand Mr.
quite serious.

The PAST-PRESIDENT said they were getting hold of the wrong idea. He said he did not know there was £10 worth of stuff on the deck to damage. He did not say that the total value of material on the deck was only £10, but the material that could be damaged, from the fact they had no bulwarks. It was the water getting behind the bulwarks that did the damage. The damage done to loose things on deck would not make up £10.

Mr. FOTHERGILL—After what Mr. Thompson had just stated, it did not appear to him necessary to add more, but he was of the opinion the explanation rested entirely on the height of platform, design, and strength of structure. In conclusion, he begged to thank Mr. Kendall for his very able paper.

The following communication was received from Mr. J. Greenhow:—

DEAR MR. DUCKITT,

The importance of this interesting paper, introducing and presenting so many unique features, is calculated to draw comments from everyone connected with the mercantile marine. It comes at a most opportune time, so far as the shipowner and builder are concerned; it presents the long-looked-for silver lining to the darkened cloud of depression in shipping;* it threatens the extinction of that abortion, the progeny of the once famous and never-to-be-forgotten well-decker, and in days gone by oft-times dubbed "a splendid dividend-earning machine."

It goes without saying, in fact experience has already proved, that this new type of ship is a phenomenal success, and as the divergence from the well-beaten path of ship construction is so vast, infinite credit is due to the inventors of the system for the plucky and determined fight which they have fought and won so handsomely, overcoming and upsetting prejudices almost insuperable to the initiated professional shipbuilder.

As professional shipbuilders and engineers, let us examine the types of ships put forward by Mr. Kendall, and we will find that the claims he puts forward for the turret type are not at all overdone, as usually is the case by advertisers in vending their commodities.

Let us proceed and examine the claims put forward by the author—claims of advantages possessed by the turret type over and above the ordinary type of vessel. (See page 212.)

* See remarks under heading of "Comparative Cost of Cargo Vessels."

1.—A high navigation platform above water, etc.—Yes; all he claims here is fair and equitable; the platform is higher amidships.

2.—The turret erection is an excellent feeder, etc.—Yes; it must be granted it is an excellent feeder, and this is a most important factor so far as the safety of the ship is concerned, especially in carrying grain. Here is a case where it would be superfluous to fit shifting boards.

3.—The curved sides of turret erections, etc.—Yes; we must allow the claims of Mr. Kendall here.

4.—The shell-plating, etc.—Yes; this can be fairly claimed; it might be taken as one of the features of the structure.

5.—There is no well or place in which large bodies of water can lodge, etc.—Quite true; there is not.

6.—By providing a high navigating platform, etc.—This is one of the peculiarities of the invention, dispensing with sheer; this is covered by advantages claimed, marked Nos. 3, 4, and 7.

7.—By increasing the depth of girder, etc.—There is an element of doubt in this claim, owing to the formation of the cross section.

8.—In the turret erection every part of the structure, etc.—Yes; this claim may be allowed. (By the way, why have the inventors not raised the sides of the inner bottom, thereby gaining a further reduction of tonnage?) The internal capacity of the vessel need not suffer, as the centre might be depressed in the same proportion as the sides are raised.

Proceeding to summarise the above claims, the following may be deduced:—

Maximum strength of construction,
" deadweight,
" freeboard to navigating platform,
" range of stability,
" size of hatchways;

and

Minimum displacement,
" registered tonnage,
" draught,
" propelling power,
" cost of construction,
" " working.

What may we deduce from the above features of this new form of ship? Simply that for deadweight cargoes, and for such cargoes as will immerse the vessel to her approved load-line, she must be a vastly superior ship to the partial-awning-deck vessel, and also superior, but in a somewhat lesser degree, to the single-deck ship.

With reference to the author's remarks anent carrying deck cargoes on the turret type, it must be admitted that a grave element of danger would become involved.*

Here, for instance, is capital earning-power for this new type of vessel. Coals from the United Kingdom to a Mediterranean port, then up the Danube for maize for home; then, again, for carrying coals to London from Newcastle this new type is peculiarly well adapted.

Strength of Structure.—This is an important feature considering the heavy cargoes now carried in one bottom. With due deference to the author's remarks anent this subject, I submit that it would not be difficult to raise the line of neutral axis in the one case, and lower it in the other; but in any case one must admit that the turret type presents advantages, so far as sagging strains are concerned, far and away superior to the partial-awning-deck type. Some builders of this last-mentioned type lay the keel blocks with 3 inch or 4 inch camber, so as to allow for sagging; this reprehensible practice should not be allowed. If there is a want of rigidity in the structure when new age will not improve it.

In the turret system it is true what Mr. Kendall claims, viz., greater depth of girder amidships, but the form of the cross section must be taken into consideration; hence, if he could at some time verify his calculation by practical demonstration, say, by sighting the vessel before launching, then when afloat, and so on, and give us the results, it would be of the greatest possible value.

Stability.—Let us now consider this important feature. The diagrams are most interesting, and go to show that this new type of ship must possess, what many ships afloat cannot boast of, viz., a somewhat high metacentre. This is what one might expect, everything considered, 2 feet 9 inches appears a most suitable G.M.; it should not be reduced to any appreciable extent, and for this reason deck cargoes should be avoided if the G.M. is unfavourably affected.

Comparative Cost of Cargo Vessels.—In conclusion, we will touch lightly on this subject, the most important point as far as the shipowner is concerned. Can the turret type of ship be produced as cheaply as the ordinary tramp? Look at the cross section and profile, and the practised eye of the practical shipbuilder will at once perceive that the plans, whilst indicating a simple method of construction, yet the simplicity is combined with splendid mechanical precision, rendering the workmanship easy to a degree; therefore we may deduce (assuming the material being similar in weight to that in the ordinary type of ship) that the new type

* See remarks under heading of stability.

possesses all the elements of favourable comparison of first cost; hence to the wary sixty-fourther, here is a chance of returning to the palmy days of yore, when 30 per cent. dividends were expected and not considered extraordinary.

Finally, these remarks are not made with a view of drawing investors into shipping; my object being to show, so far as my experience and judgment goes, that this new type of vessel, from a mechanical point of view, is immeasurably superior for cargoes before-mentioned, and possessing commercial advantages over and above the ordinary type of ship without the shadow of a doubt.

Yours faithfully,

J. GREENHOW.

Mr. J. G. JORDAN thought Mr. Kendall should be commended for his paper, and the Messrs. Doxford congratulated upon the new type of ship introduced. The main objection he had to the paper was that the comparison was restricted to one dimension of ship. There was a dimension which would show maximum ratios for any type of ship, and those who would take the trouble of referring to the tables produced by Mr. Thompson when President, and the figures he (Mr. Jordan) had the privilege of laying before the Institution afterwards, would find that the ratios varied with the different dimensions, and his point was that in this paper the comparison was restricted to one vessel, carrying about 3,800 tons deadweight. If those comparisons had been carried through with larger ships the turret type would probably have approached nearer the results of the partial-awning, spar, and three-deck types as a deadweight carrier. If they took the "Royalist," one of the largest of the turrets yet built, which had been stated to be a 5,100 tons deadweight vessel, her ratio of net tonnage to deadweight was 2·52, while the turret ship dealt with by Mr. Kendall gave a ratio of 2·75. (He had since seen the deadweight of the "Royalist" given as 5,200 tons; this would give a ratio of 2·57.) Now, as the dimensions of the types increased the ratios varied, and in this instance it is shown to be lowered. It is known that both spar and three-deck vessels have carried deadweight equalling two and a half times their net register tonnage. He thought these types ought to have been compared with the turret type instead of the single-deck vessel. He thought the value of the paper would have been increased if Mr. Kendall had carried his comparisons further than he had done. As the dimensions of the turret-deck type increased they would

probably more nearly approach the deadweight capacities of the other types of ships. This was the experience with partial-awning, spar, and three-deck types.

Capt. D. B. MAIL asked Mr. Doxford if he understood him to say he could build a turret-deck cargo boat with a capacity of 60 cubic feet to the ton?

Mr. C. D. DOXFORD—Yes; with a capacity of 60 cubic feet in the hold for every ton deadweight she would carry.

Capt. MAIL said according to his experience, that was the measurement of Alexandria cotton seed, and he had never heard of or seen a cargo boat that would load her deadweight of it, or anything like her deadweight of it.

Col. ROBSON—Cotton seed is not deadweight; for a ton deadweight of cotton seed they must take twice the quantity of coal.

Capt. MAIL said his question was—Did Mr. Doxford say he could build a turret-ship that would load down to her load-line with cargo measuring 60 cubic feet to the ton?

Mr. C. D. DOXFORD—Yes; and he would be very pleased to take the gentleman's order.

The discussion was again adjourned.

THE METRIC SYSTEM OF WEIGHTS AND MEASURES: A PLEA FOR ITS ADOPTION IN THE UNITED KINGDOM.

By G. H. BAINES.

[Read before the Institution in Sunderland, on the 24th April, 1895.]

The members of the Institution will be aware that the House of Commons has nominated a Select Committee, which is now sitting, with Sir H. E. Roscoe, M.P., as its chairman, "to enquire if any and what change in our weights and measures should be adopted." Having for many years taken an interest in the matter, and being a member of the new Decimal Association, the writer has been invited by that society to give evidence before the Select Committee. But as such evidence could only represent the expression of the opinion and experience of an individual person and firm, it was thought more desirable to ask this Institution to consider the matter, and if it thought well, to pass a resolution in favour of the adoption of the metric system by law at some early date. In conversation with the President and the Secretary, it was found that the subject had not previously been brought before the Institution, so at the request of the President this paper has been prepared. Its object, primarily, is to secure the careful consideration of the subject in its practical, commercial, and educational aspects, by a body of men whose connection with the commercial interests of this part of the country, and whose business relations with foreign countries are of such an extent as to make an expression of their opinion of value if laid before the Select Committee of the House.

The new Decimal Association is a body established to promote the adoption of a decimal system of weights, measures, and coinage in the United Kingdom. It includes not only many members of both Houses of Parliament, but of Chambers of Commerce, School Boards, Trade Councils, bankers, engineers, electricians, manufacturers, and merchants, together with many of the influential scientific professors of our universities and learned societies. On its executive committee, amongst others, are

Lord Kelvin, Sir Guilford Molesworth, K.C.I.E. (of pocket-book fame), Alexander Siemens, Col. Robson (one of the members of our Institution), of Sunderland, and a shipowner, in Col. Sir E. S. Hill, M.P., of Bristol.

The association has decided to confine its attention for the present to weights and measures, leaving any change in the coinage to the future, and has been instrumental in procuring the appointment of the Select Committee, now sitting, on the subject.

The importance of inducing this nation to adopt the metric system is shown by the fact that on the one hand by our enormous export, import, and shipping trade we have all the world for our clients; on the other, all the rest of the civilised world (423,504,561 people, including 60 per cent. of our own customers, with two principal exceptions, Russia and the United States of North America) have adopted, and will not change from, that system. It is expected that Russia will adopt it if we do so; it is used in Russia already in commercial life; and in the United States the metre and kilogramme have been adopted as the fundamental standards of length and weight. The attention of Congress and the commercial bodies have been actively drawn to it. There is no doubt that the two great English-speaking nations on the Atlantic would immensely benefit by its adoption.

The Trades Union Congress discussed this question in 1892 and 1893, and have passed resolutions approving of legislation in its favour, and of its general adoption, so that opposition from the working classes, which is alleged to be one of the difficulties of the introduction of the system, is turned in flank by the action of their representatives.

But the most eager supporters of the adoption of the metric system are our various Chambers of Commerce, who are unanimous in recommending the change. It cannot have a more powerful advocate than the widely esteemed chairman of the Associated Chambers, Sir A. K. Rollitt, M.P., who, in a recent speech, supported the appointment of this Select Committee. Sir Albert then said (*inter alia*):—"To the transposition of specifications, losses of orders for machines were due, whilst even the order for an armour-clad was said to have been lost to us owing to necessary niceties of adjustment, and to the difference of our arithmetical language from that of the purchaser." It is to be hoped Sir Albert has been misinformed; but it reveals the danger of our notation to our foreign trade. He further said:—

Why, even the Japanese had outstripped us, and positively China had placed an order with Krupp, at Essen, rather than face our vulgar fractions. We might well follow the victorious Japanese; for when he was in Huddersfield recently with the

Chambers of Commerce, a Yorkshire clothier said to him, in his rich dialect: "Them Japs, Sir Albert, are real clever fellows. They are rare bargain-makers when they come over here. They can calculate anything." But, after all, there was still some consolation for he (Sir Albert) said: "What, Mr. ———, do you mean to say they get the best of you?" "Oh, no," replied the clothier, "but then I'se Yorkshire!" And what were and would be the consequences of this insular commercial isolation? Once we were monopolists; we could force our goods on foreigners. But the great Lord Derby had said, so long ago as 1836: "The Continent will not always allow England to be the workshop of the world." And now we had to meet competition, seek and bid for orders, and find new fields of commerce. And for these purposes, there was one ever-increasing condition—that our language, our specifications, our price lists, our quotations, our invoices must be such as our buyers can read and understand. Translate and convert them they would not, and in this they only showed their human nature, for even our own language was full of proofs of the unwillingness of men to take trouble if they could avoid it. Here, then, our system was a great impediment to trade, one which drove custom to our competitors, and which would decimate our business unless our business adapted itself to decimals. And these were not mere *a priori* commercial conclusions. Our own Foreign Office consular reports teem with warnings, all telling us that if we are too conservative, in the bad sense of that term, we must lose trade, and that if we are progressive, we may extend it. Who could hesitate? Some temporary inconvenience there must be; but so there was, and more, in Germany, with its many different states, moneys, and measures, yet within four years the work was finished, and the sooner we begin the better for business.

We endure permanently, without knowing it, greater inconveniences now than the short agony of the brief transition stage would inflict; for instance, Mr. John Kindred, the Secretary of the Newcastle Incorporated Trade Protection Society, who has been getting statistics for the Select Committee, states that cement is sold in Newcastle by bag of 224 lbs.; in London 203 lbs.; cheese in Newcastle 112 lbs. to the cwt., but in Cheshire and Stafford 120 lbs.; wheat at Newcastle is 504 lbs. to the quarter, whilst at Hull (a competing port) it is 480 lbs. to the quarter, and in Liverpool is sold by the cental of 100 lbs.; locally, English wheat is sold in Newcastle at 2 bolls per bushel; at Hexham 5 bolls; Morpeth and Berwick 6 bolls. It would be wearisome, though it might be amusing, to describe other discrepancies and absurdities of British customs, for these would all be swept away when the universally simple metric system became law; meantime these obsolete customs distinctly injure our trade and our people.

Just one personal allusion. In the textile trades of the country, which employ such a vast portion of the population, the confusion of our present system would be incredible if it was put before them in detail. Being connected in early life with this branch of trade, the writer was able to assure them that the chaos in which British manufacturers found themselves when their productions began to be brought into competition with the more accurately manufactured and described productions of

foreign countries seriously injured the textile trades of the country. This (specimen exhibited) is a statement of comparative tables showing that the counts of yarn in this country are reckoned in almost as many different scales as there are producing districts. Manchester has its own cotton scale, Bradford its own worsted scale, Leeds its own woollen scale, Huddersfield and Dewsbury their own merino or mixture scales, Leicester has three denominations of hosiery yarn scales, which again are different from the Hawick, Galashiels, and Alloa hosiery scales. We can pit the mental condition of a manufacturer who had to remember these varying scales before he could make his purchases, and we can picture the discomfiture of the English manufacturer when the foreigner came along with his one uniform metric scale of so many metres per kilogramme, which obtains for all classes of woollen and cotton goods. Lord Kelvin has termed our present condition a "brain-worrying and intellect-wasting system." As a writer in the *English Mechanic* of the 22nd March says, "all this unnecessary waste of time and trouble, both in working our own wicked system and in having to translate between it and the metric system, is due to the intense obstinacy, nay pig-headedness, of the English people; the same obstinacy which makes us cleave to the Fahrenheit scale of thermometer, based upon an entire scientific misapprehension, with 180 spaces between boiling point and zero, instead of the easily worked 100 points used upon the Continent.

Turning to some of these facts in connection with our trade abroad, the British consuls, who are impartial witnesses, in countries where the metric system is in force, have recently been asked to give their opinion as to the effect of the maintenance of the English system. The following extracts will surely convince the Institution of the magnitude of the evil of our present system, and the commercial necessity for the early adoption of the metric one :—

ROTTERDAM, October 22nd, 1894.

The simplicity of the metric system is so obvious, that its adoption in England cannot fail to be of great advantage to all interested in the trade with those countries where it is already in vogue.

MILAN, ITALY, October 18th, 1894.

As an engineer of some twenty years' residence upon the Continent, I have no hesitation whatever in stating that the present system of English weights and measures is detrimental to British commercial interests in countries like this, where the metric system is in force.

The sooner the metrical system is adopted by Great Britain the more advantageous for her commercial interests when trading with the Continent in particular, as also to facilitate home calculations, especially in engineering departments, where excessive accuracy is an absolute necessity.

VARNA, October 23rd, 1894.

If the quotations and specifications in trade lists are made out in English standards of weights and measures, intending purchasers here generally throw them aside and consult others which give the required information in metres, kilogrammes, etc.

In the Varna Trade Report for 1892 it is mentioned that it is especially in hardware and machinery that the non-adoption of the metrical system acts most prejudicially against British manufactured goods.

MALAGA, October 23rd, 1894.

I have heard purchasers here say that they bought German goods in preference to English ones because German merchants sent out their price lists made out with the prices in Spanish currency and weights according to the metric system, whereas the British merchant always sent his made out according to English weights and currency.

I consider that British trade with Spain would increase if we adopted the metric system.

ROUSTCHOUK, BULGARIA, November 19th, 1894.

I know of cases where British trade has suffered because English goods offered for sale here have been made to English instead of metric weights and measures.

Since the Bulgarian Government adopted the metric system it is evident that the metre has a great advantage, and it is a fact that British imports have fallen off, while Austrian and German have increased.

BAHIA, November 23rd, 1894.

Dealers here will often throw down an English catalogue or price list owing to the difficulty they experience in calculating the cost of goods per metre or per kilo, when the quotations are made per yard or per pound.

TOKIO, January 1st, 1895.

I believe most confidently that the adoption of metric weights and measures for English manufacturers would be of benefit as far as regards their import, into Japan.

BULGARIA (Report No. 1300 of 1894).

The metric system is the one now employed throughout Bulgaria, and it is useless for English manufacturers (especially of machinery and hardware) to expect that their potential foreign customers will give themselves the trouble of learning our avoirdupois and dimension tables, in order to be able to puzzle out quarters, pounds, and ounces, yards and inches, gallons, pints, etc., into their metric equivalents.

Another reason for which it is becoming increasingly necessary for us officially to adapt ourselves to the metric system is the fact that in the world of science, and in those trades and professions which involve scientific features in their development, its adoption is forcing itself upon us. For instance, in chemistry (touching as it does so many of our industrial arts in various points), we know that in the chemical trade of this district Continental experts and traders tread on the heels of our manufacturers. In the manufacture of scientific instruments, including in that term artillery and other instruments of precision, optical instruments, medical instruments, and the like, the metric system is used because of its greater accuracy, and because of its opening up the technical teaching and results of Continential scientists and manufacturers which are recorded in metric

language. More important still, the whole electrical world has based its units for denomination and description on this system; telegraph and telephone wires are gauged in millimetres; we buy our electric light carbons by "so many millimetres thick." Sir Philip Magnus has pointed out that in accepting the Board of Trade electrical unit the Government has already adopted the system. The great importance to this Institution of the forward movement in the use of Electrical power has been prominently set forth by our President, in his valuable inaugural address on that subject, by Mr. Mountain, and others. The advantages we hope to reap will thus compel acquaintance with it. Photographers are feeling the want of it, many of the formulæ for their solutions and work being given in metric weights and measures. In the copper ore trade (one that also affects this district) the want of it also acts prejudicially. A smelter on the Pacific coast says that "many a good shipment of matte or ore has gone to Freiburg instead of to Britain because the owner wanted an account he could understand." The leading mining organ of the United States, for the same reasons, advises shipment to Germany instead of to England.

In all these, and in other trades, the necessity for great exactness and concentration of thought and accounts, has brought about the use of the metric system already, and business, to be successfully conducted in these arts, compels a knowledge and use of it.

This Institution is also an educational institute, assisting to train its juniors to skill in their profession—a most valuable and interesting section of its work. The Institution may do good educational work by informing and interesting its Graduate section in this important commercial, scientific, and educational movement, for the educational side of this question is also one of great national importance. It has been calculated by those experienced in the profession, that the time now wasted by English children in learning the barbarous tables, troy, apothecaries, avoirdupois, liquid, square, cubic, and linear measures, would be reduced by more than one-half (some say a much greater proportion) if the metric system were the only system in force in this country. Comparisons have been made in the time taken in the elementary schools on the Continent with the time taken by English children in acquiring facility in arithmetic. In elementary schools it is usual to devote one hour a day to arithmetic, and as each scholar is supposed to be about one year in each standard, it is calculated that at least two years' teaching in arithmetic is now taken up by teaching that which the metric system would render wholly unnecessary. Those who have witnessed the great simplicity of the teaching of arithmetic in foreign schools will readily believe

this to be the case. The leading School Boards of the country are in favour of the reform, and the Education Department is preparing the way, so that those who are now in our schools will, when they come to take up the business of life, be so acquainted with the metric system that the transition to a large portion of the population will be comparatively easy. We each remember the agony through which we passed in learning these multifarious tables. Surely, when a better system is before us, our children have the right to demand from us that their brains shall not be tortured with this useless, unnecessary, and cumbersome compilation. The time so wasted might be used in developing their faculties and increasing their general store of knowledge in many other directions.

In March, 1894, the National Union of Teachers at Oxford passed unanimously a resolution stating that the interests of commerce and of education demand the introduction of a decimal system of money, weights, and measures.

In 1891, to a deputation to the Education Department, in which the school boards of the leading towns of the country took part, Sir W. Hart-Dyke (the late Vice-President) said he had long been in favour of the system, and as the education of our children must be suitable to their progress and success in life, he would be glad to forward the object of the deputation. Since that time the Education Code has required that scholars in Standards V., VI., and VII. should know the principles of the metric system, and be able to explain the advantages to be gained from uniformity in the method of forming multiples and sub-multiples of the unit.

During the present week the writer held an examination of some of the children in the upper standards of the Board Schools of this town, and would circulate round the room some of the questions and the answers of the scholars, showing the simplicity of the system and the ease with which children acquire it. Round the room are charts of the weights and measures of the metric system which are hung up in our schools, familiarising the children with the subject.

In addressing a commercial and scientific assembly such as this, it may be taken for granted that the members have more or less a knowledge of the nomenclature and characteristics of the metric system. Can we say the same, that they have to-day an exact knowledge of our present foolish, complicated, and time-wasting tables? For the sake of those who are not so familiar he would briefly indicate the salient points of the proposed system.

The metric system of weights and measures is wholly based on the metre, alleged by its authors, in 1799, to be one ten-millionth part of a quadrant of the earth's surface, measured from the North Pole to the Equator through the meridian of Paris. Be that a scientific fact or *une idée magnifique* of our gallant neighbours, the metre so devised has become the basis of this universal scheme. A standard measure, the "line-metre," was sent from Paris to our Standards Office in Westminster in 1889, and at the same time the standard weight, a kilogramme. In 1894 the standard "end-metre" was received. They are made of an alloy of 90 parts of platinum and 10 of iridium, found by experience to be the least affected by change of time and temperature, and also to take the marking most easily.

The METRE is 39·3708 English inches, and is the unit of length. The unit of surface generally used is the square metre, or 1·196 square English yards, but in measuring land the "are" of 100 square metres—119·6 square English yards—is used, and for large portions, the hectare of 100 ares, or 10,000 square metres, or nearly 2½ acres. For volume or bulk the unit is the "stère" or cubic metre. Each metre, are, or stère is divided into tenths, hundredths, and thousandths when fractions are required, and for larger denominations they are multiplied in powers of ten.

Now comes the science of the system and its symmetric beauty. It took the French scientific men five years to devise it, and four years more in which to perfect the standards before they were officially adopted in 1799 to 1801. Having a theoretically perfect measure they decided that weight and capacity should be so co-related to it that the whole system is one and inter-dependent. They took the length of a hundredth part of a metre (centimetre) as the basis of a cube, and said that a cubic centimetre of water at its greatest density should be the standard of weight, calling it the GRAMME. Some rough models of cubic centimetres were exhibited. The gramme is equal to 15·432349 grains troy, or ·035 of an ounce avoirdupois. The gramme is divided and multiplied as required by powers of ten.

Still retaining the cubic centimetre they resolved that 1,000 of them should be the basis measure of capacity for dry and fluid measures, and called it the LITRE, equal to 1·760 English pints, 61·02 cubic inches, or ·22 of a gallon. The litre is multiplied or divided by powers of ten. Everything is decimalised, there are none of the eccentric multiples of English nomenclature. (Various specimens exhibited.)

The multiples of the metre, gramme, and litre, or basis standards of length, weight, and volume, are known by the Greek words signifying

powers of ten—deka 10 times, hecto 100 times, kilo 1,000 times, myria 10,000 times the basis; thus kilometre is 1,000 metres, and is the metric mile or measure for long distances; it is 1,093·6 yards. Kilogramme is 1,000 grammes, equal to 2·2046 lbs. avoirdupois; it is the almost universal weight, and is found to be so convenient that in common domestic and commercial life it is the standard, and is generally used up to the ton or 1,000 kilogrammes, without using the intervening names. For instance, duties are levied by the "100 kilos" instead of by the quintal. In common life, however, the ½ kilogramme (500 grammes) is in France still used as the "livre," and in Germany as the "pfund" or lb., being very near the English pound; also 250 and 125 grammes are spoken of as ½ and ¼ livre or pfund. This retention of the familiar name of lb. (being within a small fraction the same as it is now) will lessen the difficulties of the introduction of the system into Great Britain.

For divisions of the metre, gramme, and litre, the Latin words for powers of ten are used; deçi, the tenth; centi, the hundredth; milli, the thousandth; thus a millimetre is the thousandth of a metre or ·0394 of an English inch (25 being almost an inch, makes an easy memorandum), and it is the standard for rules, gauges, and similar appliances.

To remember the relation of the Latin and Greek terms for ten, which are confusing at first, put a çedilla (under) the Latin subdivision deçi, and a tall k (above) deka for the Greek multiple.

There are some further interesting co-relations of the system. These units have simple relations to each other. Thus, the cubic centimetre of water is 1 gramme, a cubic deçimetre of water (1,000 cubic centimetres) is 1 kilogramme, and a cubic deçimetre of water is 1 litre also. A model of a cubic deçimetre marked in subdivisions of centimetres and millimetres, showing linear, surface, and cubic measurements was exhibited.

As one litre contains a kilogramme, so one cubic metre (1,000 cubic deçimetres) contains 1,000 kilogrammes or one metric ton of water. This is the factor for calculation of the tonnage of ships, and as it weighs 2,204·62 lbs. avoirdupois against our 2,240 lbs. to the ton, this slight difference brings the general idea of the two systems in mental comparison in large weights very close together; it is also 1 kilolitre.

The specific gravity of a substance is its weight in relation to that of water, and as the weight of water contained in any metric measure of volume is known, it follows that the weight of any substance can be easily found, when its bulk in terms of the metre is known, by multiplying the latter into its specific gravity. Or, if we know the

weight of any substance, we can easily find its volume by dividing the weight by the specific gravity. For instance, the weight of a boat load or store of corn, lime, or other substance can be ascertained by multiplying the length, breadth, and depth in metres by the specific gravity. The result will be the weight in kilogrammes. On French slide rules it is customary to give the specific gravity of common substances, such as wood, iron, stone, etc., for the purpose of assisting these everyday calculations.

The set of metric tables in ordinary use, discarding unused intermediary denominations, is as follows. These are the terms in common use in countries which use the system, and even some of these are rarely used:—

Measure of Length.

1 millimetre	·0394	inch.
10 millimetres make 1 centimetre	·3937	"
10 centimetres make 1 deçimetre (hand)	3·937	"
10 deçimetres make 1 metre	39·3708	"
1,000 metres make 1 kilometre	1093·6	yards.

The millimetre, centimetre, metre, and kilometre are the ordinary terms.

Measure of Surface.

100 square centimetres equal 1 square deçimetre... ...	·119	square yards.
100 square deçimetres equal 1 square metre	1·196	"
100 square metres equal 1 are	119·6	"
100 ares equals 1 hectare equals 10,000 square metres ...	11960·0	"

The square centimetre and square metre are the ordinary terms.

Solid or Cubic Measure.

1,000 cubic centimetres equal 1 cubic deçimetre (equals 1 litre of water).
1,000 cubic deçimetres equal 1 stere or cubic metre or ton, 1·308 cubic yards.
The cubic centimetre and metre are the ordinary terms.

Measure of Capacity.

10 centilitres equal 1 deçilitre.
10 deçilitres equal 1 litre = 1 kilogramme = 1 cubic deçimetre, = 1·76 pints.
100 litres equal 1 hectolitre (or 22 gallons).
1,000 litres equal 1 kilolitre (equals 1 cubic metre or ton).
The centilitre, litre, and hectolitre are the ordinary terms.

Weights.

1 gramme equals 1 cubic centimetre of water (or 15·43 grains).
100 grammes equal 1 hectogramme.
1,000 grammes equal 1 kilogramme (equals 2·206 lbs).
1,000 kilogrammes equal 1 ton.
The gramme, lb. (500 grammes), kilogramme, and ton are the ordinary terms.

It is quite a mistake to alarm our children or our workmen with the pains of a vast number of new terms; an hour's study of the chart and handling of models will remove all difficulty.

The following table shows the comparative elements and relative values of the terms used:—

Length.	Surface.	Notation.	Weight.	Capacity.
—	—	1,000,000	Ton	—
—	—	100,000	Quintal	—
Myriametre	—	10,000	Myriagramme	—
Kilometre	—	1,000	Kilogramme	Kilolitre
Hectometre	Hectare	100	Hectagramme	Hectolitre
Dekametre	Dekare	10	Dekagramme	Dekalitre
METRE	ARE	1	GRAMME	LITRE
Deçimetre	—	·1	Deçigramme	Deçilitre
Centimetre	Centiare	·01	Centigramme	Centilitre
Millimetre	—	·001	Milligramme	Millilitre

It will be expected that this paper should deal with some of the difficulties which are supposed to have hitherto prevented the adoption of the system. It need only deal with the professions with which we are connected—the shipbuilding and engineering trades; so far as can be gathered the great majority of the other trades in the country would welcome the adoption of the system. So far as shipbuilding is concerned the lengths, weights, areas, and cubic capacities dealt with are of such large denominations that there would seem to be very little difficulty in the transition. Measurements are made in metres and decimals, areas in square metres, and contents in steres or cubic metres. The thicknesses of plates and other small dimensions are made in millimetres or centimetres.

The members of the Institution must in their business relations be constantly receiving drawings of ships and machinery from abroad with metric weights and measures inscribed upon them. What do we do with them now? Speaking generally, we all translate these beautifully simple terms into our complicated ones, and as any given number of millimetres and kilogrammes works out to be expressed by fractions of an inch, even running into 32nds, or fractions of pounds and ounces, the difficulty of making an article to fit the required foreign measurements is endless. How much better would it be if the greater simplicity which Continental manufacturers enjoy was also enjoyed by our own workmen, draughtsmen, clerks, and principals, saving the large amount of inconvenience occasioned by the reduction, which not infrequently leads to mistakes, with the attendant lost time and money.

So far as can be seen there is only one practical difficulty to be faced in our works in this district. We have a large number of gauges of all sorts, chasers, taps, dies, and the like, which cannot be altered,

do not wear out, and are too valuable to throw away. Then there is the question of the screws with their threads, and all that follows the use of the screw upon a machine tool. The adaptation of these needs special consideration, but on detailed enquiry many difficulties lessen and disappear.

We all have work to do in repairing existing machinery and ships, the old tools would have to remain to serve them, as new parts must be made to fit the main portion, and the drawings remain in inches; and would suggest that our practical works' managers hold a conference to evolve some method by which there would be a lessening of the necessity for renewal of so many valuable appliances, and of suggesting arrangements by which many existing tools could be used with the new methods. The Board of Trade, together with the surveyors to the classification societies, could render very valuable aid in considering the limits of change and in lessening its effect. By stamping existing tools and gauges with the metric equivalent much may be done. But to some extent for new work our makers of screw appliances, such as Whitworth, will have to give us new appliances when they have themselves prepared them. The transition in Germany must have caused the same trouble that we have to face, but the universal testimony is that it is less formidable than it appears. On the Continent, Whitworth threads are still largely used: what is wanted is an "international agreement on screw threads." This part of the subject, however, is too much a matter of detail to be treated of in a general paper. But, in view of the enormous general advantages to be gained, the shipbuilding and engineering profession can and will turn the flank of these smaller difficulties.

The personal difficulties of the change to our engineering and boiler making workmen will be very small; we shall put into their hands first rules marked with inches and millimetres till the drawings be altered. Some specimens have been procured which are marked in both notations, and are very low in price; also specimens of the actual rules in use in French and German engineering shops; the half-metre (cubit) is a common size, marked in millimetres and centimetres. Weights will have to be taken in kilogrammes. For a time there will be some confusion; managers and foremen will need extra vigilance, having first mastered the principle themselves. But what could be done in Norway, Sweden, and Germany can be done here. Mr. E. H. Bayley, M.P., said he had been every year to Sweden, where the change was recently made, and he was astonished at the ease with which the common people understood the change. Six months before the change the Government

stuck up posters in the market places and freely about the country explaining the system; small handbills were freely spread through the houses. Mr. Alex. Siemens bears testimony to the ease of the transfer in Hanover. In Austria, too, the change was made without the great difficulties and upsetting of business prognosticated. What they can do we can do; it is all a question of education and sufficient notice.

Some testimony may now be given as to the excellent effect of the metric system on the workmen and work, on the changes to be faced, and the slight difficulties involved.

The following letter from Colonel Dyer, one of the directors of Messrs. Sir W. G. Armstrong, Mitchell, & Co., Limited, of Elswick Works, is valuable testimony as to the real smallness of the difficulty in making the transition from our system to the metric one:—

Dear Mr. Baines,—I wish I could assist you with some facts for your paper on the metric system, but I am sorry to say I have none, because we have never used the system here beyond decimalising the inch, and at the Pozzuoli works the metric system has been in use from the commencement. The consequence is that each works knows only the one system and they have never tried the other, they cannot therefore compare the two.

I was for several months at Pozzuoli when first it was started. I had therefore that amount of personal experience with the metric system after having been all my life used to the other; for the first week or two the change was a little puzzling, but when once the mind got used to the difference and you thought in centimetres and millimetres—in litres and kilogrammes—the advantage was most marked, and I have no hesitation in saying I returned to our English system with the greatest regret, and I found far greater difficulty in training my mind back to feet and inches than I had to forget them.

Personally, I have a strong preference for the metric system both for mechanical as as well as for financial work—my preference comes after a fair trial of both systems, and I hope I may live to see it generally adopted.

Yours very truly,

(Signed) H. Dyer.

The firm of Herr Fried. Krupp, of Essen, the famous manufacturer of ordnance, has kindly allowed one of their managers to say that their experience is that accurate measuring is much easier with the metric system, and that less skilled workmen are required for exact measuring than with inch rules. They also find in reading off small fractions from an English drawing that mistakes are more easily made. In working to English drawings, if particularly exact results are desired, they transform them into metric measures.

Mr. Hans Johansen, assistant surveyor to the Norske Veritas, a Norwegian, residing in Havre, who has also a good knowledge of English workshops—thus knowing the practice of three nations—has given

some practical information on the use and advantages of these measures in Continental workshops. He says that in machine shops the principle of decimalisation is found specially advantageous, enabling the fitter to measure very quickly and with great exactness. The English two-foot rule is in most French workmen's hands replaced by two rules:—(1) The ordinary pliant metre-measure of yellow metal, folding up into decimetres (specimen exhibited); and (2) the "pied à coulisse," or sliding rule (specimen exhibited). Ordinary workmen use the yellow-metal metre, and it is marvellous how practice enables a man to manipulate it with certainty, although for long measures, the wear of the many joining rivets makes it less exact. In Germany the workmen use the steel "metre à etalon" or "standard metre" (a German and French steel demi-metre workman's rule exhibited), marked in millimetres and centimetres only. This, of course, is a more exact tool than the yellow-metal one. In French shops this "metre à etalon" is also used, especially by foremen and draughtsmen, and workmen get them when needed. The second tool, the "pied à coulisse," is an ingenious instrument for taking the internal and external diameters of objects to an exactitude of one-tenth of a millimetre, a dimension which certainly is minute enough for engineering purposes. This is done by means of a vernier fixed to the reading-off scale. With these two rules and the decimalisation of measures, it seems that a vast saving both of calculation, time, and labour will be achieved in our shops; certainly it is a powerful plea for the metric system. Smiths and boilermakers use only the yellow-metal metre in France.

In pattern-making the metric system lends itself to the making of scales to denote and suit the differing shrinkages of the various metals to be cast. Mr. Johansen has seen a pattern-maker with seven differing scales on the metric basis to suit his different sizes of pieces. That gentleman also uses a micrometer with a vernier, for making and checking the transformation of the millimetre into inches, and *vice versâ*, in dealing with the thickness of plates, rivets, and the like, in boilers and ships. This, with tables converting the $\frac{1}{16}$ and $\frac{1}{20}$ of an inch now in use for iron and steel plates by the classification societies into metric sizes, enables him to work easily in both systems. But he goes on to say, and it will be at once admitted by this Institution, that a principal advantage to our professions, combined with a great saving of time, labour, and mistakes, is the use of the metric system in the making of drawings and tracings in our drawing offices. These would all be in decimals, instead of in $\frac{1}{16}$ inch, $\frac{1}{8}$ inch, and $\frac{1}{4}$ inch, with the various reduction-scales we

use; this economy makes a powerful plea in favour of the metric system, outweighing in the long run the cost of renewing our measuring apparatus. In our drawing offices, too, the advantage of the instant calculation of the weight of a given design in any ordinary material is very great. Knowing the density of a material (many "specific gravities" are marked on slide rules) without any special table, a draughtsman is able rapidly to state the weight of a required article without the intricate calculations of our ozs., lbs., qrs., and cwts., with their powers of 16, 28, and 4. In this connection, it may be stated that Sir Guilford Molesworth has recently published a supplemental pocket-book in which the transformation of English to metrical, and metrical to English, sizes is given in the most complete detail (copy exhibited). All necessary formulæ, not only in the ordinary measures, but in such combinations as are needed by shipbuilders and engineers are given, *e.g.*, foot-pounds into kilogrammetres, pounds per square inch into kilogrammes per square centimetre, pounds per square foot into kilogrammes per square metre, pounds per square inch into atmospheres, pounds per yard into kilogrammes per metre, horse-power into *force de cheval*. With such clear definitions as these it is certain English manufacturers, draughtsmen, foremen, and mechanics can easily adapt themselves to the modern necessity of the metric system.

The question of the decimalisation of our coinage is postponed. Everyone admits that the British £ sterling in gold must be maintained. There is, on the other side, the enormous use of the penny, and to alter its relation to the sovereign is a difficult matter. It is not insuperable—10 farthings to a groat, 10 groats to a florin, 10 florins to a £ would make very slight changes. Bronze coins are tokens, and by the addition of pieces of the value of 3 and 5 farthings (the 3 farthings coin might be made slightly angular, say nonagonal, for distinction) the varying pieces would enable the traders and their customers to arrange matters. But as it is not before the country it is not needful to discuss it. It is named to point out that in connection with a metric system of weights and measures a decimal coinage would be an additional boon and simplification of our domestic and commercial and educational life.

It may be asked, how do you propose to bring about the change? It is suggested that Parliament should pass an Act making the use of the metric system (1) optional at once, and (2) compulsory at some future date, say, in five years' time (on 1st January, 1900). Between this and that time the Education Department, and the trustees of secondary schools and colleges, will have given special attention to the training of millions

ıd. students therein. Through them large masses of the
ll become so familiar with it that the knowledge of the
ıven the home and retail trades, so that when the proclama-
e at the given time, the country will be ready to reckon,
ell on the new basis, and will, probably, speedily ask for
ion of the coinage also. For the benefit of manufacturers the
nt might appoint small roving technical commissions, to hold
special trade enquiries up and down the land, to enquire into
importance to traders, such as that have been referred to in the
obsolete of part of the valuable appliances used in the engineering
Then through institutions like this, and Chambers of Commerce,
ormation could be dealt with by the Board of Trade, and an Order
uncil under the Act would legalise any special modification found
sary or desirable. Thus the twentieth century would accomplish the
sition with very little friction, as in Germany, and would wonder at
slowness of the nineteenth in refusing its benefits.

The writer desires to acknowledge indebtedness for information to the
w Decimal Association, and especially to a paper by Mr. J. Emerson
owson, M.I.C.E., the chairman of the executive committee of the
ssociation; to Mr. Rowlett, of Leicester, and others named above.

This paper is called "A Plea for the Adoption of the Metric System
in the United Kingdom;" and it is hoped a case has been made out to
the satisfaction of the members of this Institution, and that they will feel
assured that the international, and even national necessities for it will
immensely outweigh the temporary spasm of inconvenience to the unedu-
cated and thoughtless and thriftless portion of the community. Should
this be so, it is hoped this Institution, in the way it deems best after con-
sideration of the question, may give its valuable, practical, and scientific
testimony to the importance of the question, and lend its powerful aid to
the movement for an official adoption of the system.

APPENDIX.

Since this paper was put into type for the meeting in West Hartle-
pool, on the 6th instant, information on several points of practical
interest has been received, which it will be desirable to communicate
to the Institution.

The Select Committee of the House of Commons is as follows:—Sir
H. Roscoe (chairman), Sir J. Barran, Mr. T. Burt, Mr. Crombie, Mr.
H. Allan Gibbs, Mr. Godson, Sir E. S. Hill, Mr. Justin

McCarthy, Sir S. Montagu, Mr. Jasper More, Sir A. K. Rollitt, Mr. J. C. Stevenson, Mr. Stewart Wallace, Mr. Webster, Mr. Whiteley, and Mr. T. Wrightson.

Another official body, the Association of Inspectors of Weights and Measures, who are under the County Councils, have passed resolutions strongly approving of the adoption of the metric system in this country; this testimony of a body of men specially and officially brought into contact with all classes of the community, especially with the humbler part of the trading classes, is most significant of the desirability of the change. The writer has put down a motion of approval of the system for the meeting of the Durham County Council next week, and also at the meeting of the National Association of School Boards to be held in London in May.

The existing law on the use of the metric system is in a curious state. Contracts made in terms of metric weights and measures are good, but the Weights and Measures Act of 1878, whilst providing as above, and for verification and stamping of metric weights and measures if used for scientific purposes or manufacture, does not provide for verification and stamping of those used for trade purposes, so that any person so using them would be liable to be proceeded against for having unstamped weights and measures in use, and this has actually been the case in the drug trade in London, though in many trades the law is disregarded—surely a strong argument for unification.

Mr. Howard Livens, of Messrs. Ruston, Procter, & Co., of Lincoln, and Capt. Sankey, R.E., a director of Messrs. Willans & Robinson, Limited, have both given the writer testimony as to the practical benefit of the use of the system in the drawing offices of the companies named. Capt. Sankey has sent a communication which will be read by the Secretary. Mr. Livens also bears testimony to the advantage on the commercial side of the business, especially at such times as stocktaking, when the labour of weighing and calculation would be immensely reduced.

Information from those gentlemen and from others on the question of screw threads is most interesting. Correspondents agree that there is need for an international congress or agreement on this question. International agreement was aimed at by Sir Joseph Whitworth when he revised the system of screw threads as we now use it. But the Americans would not adopt it, taking a standard of their own, and there is great diversity of practice on the Continent; for instance, an English manufacturer says that in taking foreign orders he always has to ask

what pitch of thread is required, as it seldom happens that two fi have the same number of millimetre-pitch for a given diameter of m metres; in Britain the diameter being given, the pitch is known. T interesting facts may be noted. An order from a technical school Continental "metric" country for some Whitworth screwing tackle, bot pitch and size, has been placed with a British machine tool firm wl does not make the tackle and does not use metric measures. Ag some taps have been ordered for a new water-tube boiler of 2½ m metres pitch, but to English diameter in inches. Can there be greater argument for unification than the confusion represented by tl circumstances? It is a fact, however, that the Whitworth threa much more used than any other in all parts of the world. These factors in the consideration of the future treatment of the screw th question—the wide international use of the Whitworth, and the diver of the practice of other nations, make possible a universal agreem This would, after examination of the evidence by experts, be prob based on Whitworth practice, in combination with an adaptation metrical nomenclature. It is stated that there is no difficulty in adoption of the metric system by our bolt and nut, and screwing tac manufacturers; on the contrary, it would simplify their business, a extend our British trade in their productions to a large extent.

The writer suggests that the Institution might appoint a committee arrange a conference on the subject with other districts of the Uni Kingdom, or, better still, pass a resolution calling on the Select Co mittee of the House of Commons to arrange for such a conference, fi national, and then international.

DISCUSSION.

Col. Robson said he was not there to instruct that meeting on metric system, but simply because he had what was called a watch brief on behalf of the Associated Chambers of Commerce, and also Decimal Association, being a member appointed to give evidence bef the Select Committee of the House of Commons on the subject. wished to see, too, if he could get out of that Institution the resolut alluded to by Mr. Baines. He had got a hint that there was no rule passing a resolution in this way; but if there was no hard and fast r he begged to press upon them the aid it would give to the movem to have the support of so influential and scientific a body as that of

North-East Coast Institution of Engineers and Shipbuilders. It was a very important subject, more than appeared on the surface, because a man might be a devotee of the decimal system and opposed to the metric system, for they were not bound to have the metric system to carry out the decimal system; they could take any standard and make it into decimals. But what the Chambers of Commerce and Decimal Association wanted was, if they changed to the decimal system, at the same time to make the change to the metric system of weights and measures, so as to enable them to carry on their commerce with other countries without having to put both their money and weights and measures into different calculations. If they had to begin to turn cwts., qrs., and lbs, as well as pounds, shillings, and pence, into foreign weights, measures, and coinage, they thought it better to have the metric system adopted once and for all. The members of this Institution would hardly think it necessary to bring evidence before any body of people whatever as to the advantages of the metric system. He had in ten years only met with one man opposed to the metric system; he forgot now who it it was, but remembered he did it from sentiment. He believed there was once a man who maintained that the earth was flat. These two, he fancied, were singular in their fancies. There could be no serious objection to the metric system, and he had come across many familiarised with the decimal system. The Government of the period always made the excuse that the people of the country were not sufficiently familiar with the system to justify them in making the change. He had been before two Chancellors of the Exchequer on the subject. They went before Mr. Goschen, and he said—"Oh, you must get the working men familiarised with the proposal." He said he thought the north country working men were quite equal to the decimal system already. The next deputation was to Sir William Harcourt, and it included some most intelligent men, armed with instructions from the great labour congress at Glasgow to represent them —one or two millions of artisans and labouring men. "Ah," said Sir Wm. Harcourt, "we quite understand the intelligent mechanic comprehending decimals, but what about the old apple woman and the Irish labourer?" That showed that Chancellors of Exchequer would shelve this question if they could, and his impression was that they had given them this Select Committee, and mixed the metric system up with the decimal system to make it more difficult and more easily got rid of. Therefore, it was all the more necessary that the evidence they put before that committee should be sound and conclusive. To get the metric system it was absolutely necessary they should have the weight of evidence of scientific men, therefore he felt that a decision come to, or a resolution carried by,

this Institution would have immense weight before a committee of t House of Commons. If it were possible to move a resolution witho infringing their rules, he should like to do so.

Mr. DUCKITT (Secretary) said the only objection to moving a reso tion would be simply this, that the members of the Institution had had notice of it. The Institution extended over the whole world, anc they wanted to get a resolution passed with the *imprimatur* of members upon it, they should have notice beforehand.

Col. ROBSON—The metric system is used pretty well all over the wor Well, he expressed a hope that this Institution, when it had finished deliberations on the subject, would send some notice of approval either Mr. Baines or himself, that the decision arrived at by this Institutio might be put before the committee of the House of Commons.

The PAST-PRESIDENT said there was another way of doing what wa asked—the next meeting could empower the Council to send a recommendation to the committee.

Mr. H. MACOLL said he would suggest that notice be given of the motion to be proposed at the next meeting, and this would be duly intimated to the members.

Mr. BAINES thought a motion at the next meeting would be in time for the committee.

Col. ROBSON accordingly gave notice that at the next meeting of the Institution he would move the following resolution :—

"That this Institution, observing that a Select Committee of the House of Commons is considering our system of weights and measures, and whether any change should be adopted, is strongly of opinion that the early adoption of the decimal and metric system would be a national benefit to the people of the United Kingdom.

It believes that it would greatly promote the expansion of our foreign trade, and also simplify business transactions at home.

The Institution is of opinion that the transition can be effected with very little hardship to traders, manufacturers, and the public generally, and that by conferences in various parts of the country any difficulties in special trades could be easily adjusted.

That a copy of this resolution be sent to Sir Henry Roscoe, Chairman of the Select committee."

The SECRETARY read the following communication from Capt. Sankey:—

DEAR MR. DUCKITT,

I have much pleasure in bearing testimony to the advantages of the metric system of measurement over the English method (or rather want of method). I have carefully read Mr. Baines's paper, and can subscribe to all he has said in favour of the metric system.

Messrs. Willans & Robinson, Limited (of which I am a director), have introduced the metre for linear measurements into their works, just two years ago, and since that time for all new work the drawings have been figured in millimetres. They had primarily been induced to do this so as to be able to work on the interchangeable system with their foreign licensees; but the advantages of the system *per se* had been a potent factor in their decision. These advantages might be summarised as follows, and the experience of two years entirely bore them out:—

(1) It is easier to design.
(2) The drawings are clearer and more easy to read.
(3) There is less liability to mistakes.
(4) Checking overall dimensions is far simpler.
(5) Marking off work is easier and less liable to error.

To illustrate the second point, photo prints of two cylinders of nearly the same size, but with some modifications in design of details, are attached. One of these is figured in inches and fractions and the other in millimetres. A glance is sufficient to show the superiority of the metric system.

The fourth point was also illustrated by the following tabular statement, showing the checking of the height of the cylinder in English and metric measurements:—

Old Series. Standard Cylinder, I. Size.			New Series. P. 600, L.P. Cylinder.	
Ft. Ins.		Ft. Ins.	Millimetres.	Millimetres.
11⅛	$\frac{1}{32}$		27	
⅛	$\frac{1}{32}$		207	
1½		1 6¾	25	496
4¾	$\frac{1}{16}$	¼	245	8
1 6⅛	. .	1 6⅛	504	504

It was anticipated at the time of the introduction that difficulties would arise. None of any moment have occurred, and not a single piece of work has been spoilt owing to the change in the method of measuring.

There has been no difficulty on the part of the men. After a few da the strangeness wore off, and all those I have personally asked state th they prefer the metric system.

What, it might be asked, are the objections to the introduction of t metric system into English engineering shops? One of the princip objections is the expense of having to get a new outfit of gauges. Th expense has to be faced, and it seems to me purely a question of whethe the advantages and undoubted savings of working due to the metric syste were a fair return for the capital thus expended. This was a questio each manufacturer must consider for himself. In our case (Willans & Robinson) I am satisfied that the cost of new millimetre gauges has bee a wise expenditure, although it has been very heavy—a great deal mor so, in fact, than would usually be the case, owing to the extensive us made of gauges at our works. The next objection was—How wer repairs to be dealt with? and this objection, of course, only referred t such repairs as were made to an original drawing figured in Engli measurements. There were only two ways of proceeding—one, to redu the English measurements to millimetres, carrying out the reduction such dimensions as "fitted" into the old work to the nearest $\frac{1}{100}$th of millimetre; and the other, to leave the English measurements as th were, and work to them in such cases. The former was the more logic the latter the more practical course, at any rate for the present, and t one they had adopted. It might be said that difficulty would arise working the two systems concurrently. That has not been my expe ence, extending now over two years. A repair effected by measuring the work itself, and not to an existing drawing in English measureme would, of course, be best carried out in millimetres.

The last and most important objection was, how to deal with scr threads. For the present we (Willans & Robinson) have retain Whitworth threads, but undoubtedly it would be better to adopt metrical thread, only so far as I am aware there is no metrical thre that holds the same position as the Whitworth thread.

I quite concur in the author's suggestion that what we want is a international screw thread, and it appears to me that the time is now rip to move in such a matter. Might I suggest a resolution on the subjec from this meeting to be forwarded to the Select Committee on Weight and Measures, now sitting, at the House of Commons.

Yours faithfully,

H. Riall Sankey,

Capt., R.E. (retired).

The meeting then adjourned.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

ELEVENTH SESSION, 1894-95.

PROCEEDINGS.

CLOSING BUSINESS MEETING OF THE SESSION, HELD IN THE LECTURE HALL OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-UPON-TYNE, ON TUESDAY EVENING, MAY 14TH, 1895.

ROBERT THOMPSON, ESQ., J.P., PAST-PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, held in Sunderland, on April 24th, 1895, which were approved by the members present, and signed by the Past-President.

The ballot for new members having been taken, the Past-President appointed Messrs. W. H. Dugdale and G. W. Sivewright to examine the voting papers, and the following gentlemen were declared elected:—

MEMBERS.

Boyd, Arthur, Engineer Surveyor to Lloyd's Register, 5, Windermere Street, Gateshead-on-Tyne.

Nichols, Walter W., Marine Engineer, 30, Denmark Street, Gateshead-on-Tyne.

MEMBER (LATE GRADUATE).

Cooper, Sidney, Engineer, 14, Northgate, Hartlepool.

ASSOCIATE.

Runciman, Walter, Shipowner, Fernwood House, Clayton Road, Newcastle-upon-Tyne.

Mr. Henry Foster replied to the discussion on his paper "On the Application of the Electric Arc to Machinery and Boiler Repairs, etc."

The discussion on Mr. S. O. Kendall's paper on "Turret-deck Cargo Steamers" was resumed, and Mr. Kendall replied.

The discussion on Mr. G. H. Baines's paper on "The Metric System of Weights and Measures" was resumed, and Mr. Baines replied.

The closing business of the session was then proceeded with.

MR. H. FOSTER'S REPLY TO THE DISCUSSION ON HIS PAPER "ON THE APPLICATION OF THE ELECTRIC ARC TO MACHINERY AND BOILER REPAIRS, ETC."

Mr. HENRY FOSTER said that in replying to the discussion on his paper, he begged to refer to the great pleasure it gave him to have had the opportunity of bringing the matter of electric arc welding before the attention of the North-East Coast Institution of Engineers and Shipbuilders, and he had to thank those gentlemen who had taken part in the discussion, and especially were his thanks due to Mr. Mountain for the valuable information given in his criticism—all of which added materially to the value of the paper.

Mr. Stoddart called attention to the fact that in the table of records of tests, the steel which had a higher tensile strength than 26 tons per square inch was not so reliable at the weld as steel having a less tensile strength. Of course, it was well known that this was equally true in regard to all ordinary carbon steel when welded in the usual way. Mr. Stoddart, however, was not justified in his general statement in regard to the ratio of elongation of the welded and solid plates, "that iron had an immense advantage over steel," nor were the figures showing the best ratios of elongation of the welded iron and steel plates given by Mr. Stoddart quite correct. The writer had calculated the ratios of elongation of the welded and solid pieces for the whole series of tests given in Table No. I., page 180, and from the recorded results as given in Table No. III. it would be seen that the best sample of steel below 26 tons tensile strength had a ratio of 24·23 per cent. and not 23·1 per cent., and the lowest ratio for Low Moor iron was 32·58 and not 37·4 per cent. as given by Mr. Stoddart. Table No. III., page 306, also clearly showed that these ratios were more irregular in the case of the iron pieces than in the steel ones when taken all round, and that therefore the immense advantage claimed for iron over steel in this respect did not in reality exist—although the ratios for Low Moor iron pieces were generally higher than the steel ones. The real comparison, however, so far as this paper was concerned, was not between electrically welded and solid pieces, but between electrically welded pieces and pieces welded in the usual way, and this comparison, as shown by Table No. II., page 182, was generally in favour of the electric welds.

welding or electric lighting on the low tension system as described by the writer, but it was only fair to the pioneers of this process to add that the machine in question was designed for lighting only and not for welding. The first machines used for welding were of ample power, which accounted for the successful results accomplished, and the disgrace referred to by Mr. Mountain, and in which the process was for a time enveloped in the neighbourhood of Sheffield and elsewhere, rested with those electrical engineers who subsequently recommended and supplied machines which were not capable of doing the work efficiently.

In this process, as in any other process of welding, it was essential that heat in volume, as apart from its intensity, should penetrate the article to be welded, and this condition could only be obtained by a long, steady, and continuous arc. With the short intermittent arc obtainable from a small machine, the material was burnt by the intensity of the heat, combined with its extreme localization.

In reply to Mr. Mountain's request for more information as to the tensile strength and elongation obtained from steel plates welded by this process at Newburn, the writer begged to say that no systematic tests had been made upon steel plates, owing to the fact that the apparatus in use there would require modification to adapt it to this special purpose, but, by request, the following tests were made by, and in the presence of, Lloyd's surveyor upon iron bars treated as indicated in Table No. IV.:—

TABLE No. IV.

RESULTS OF TESTS MADE AT NEWBURN STEEL WORKS UPON ELECTRICALLY WELDED IRON BARS.

DATE OF TEST, MAY 30TH, 1890.

Mark of Test.	No. 1.	No. 2 HB.	No. 3.
Diameter of specimen, inches	1·13	1·12	1·14
Original area, square inches	1·0028	·9852	1·0207
Fractured area, square inches	·6082	·8171	·5944
Maximum stress, tons per square inch ...	23·61	22·86	22·75
Contraction of area, per cent.	39·38	17·06	41·79
Elongation in length of 5 inches, per cent.	28	14	30
Appearance of fracture, silky, ,,	100	90	100
,, ,, crystalline ,,	—	10	—

No. 1 iron piece just as hammered—not welded.
No. 2 HB ,, electrically welded and hammered.
No. 3 ,, ,, ,, and annealed, but not hammered.

BENDING TESTS.

No. 1 transverse piece 1¼ inches in diameter, bent double—not broken.
No. 2 HB ,, ,, ,, ,, bent through 32 degs., broke, slight flaw on top side.
No. 3 ,, ,, ,, ,, bent double—not broken.

Tested in the presence of Lloyd's surveyor.

There was no particular reason why so many small resistances should be inserted in the circuit as illustrated in diagram, Fig. 2, Plate XLV. (and to which exception had been taken by Mr. Mountain and Mr. Newitt). As explained in the paper, a much more portable and equally efficient regulating resistance might be adopted, but where an ordinary arc lighting system was already in use, and where a large regulating resistance suitable for welding was not at hand, a very efficient resistance could be extemporized by taking the ordinary arc lamp resistance coils and arranging them as indicated in Fig. 2, Plate XLV. In ordinary working it was found that when sufficient resistance had been interposed to steady the arc no adjustment of the resistances was necessary. Mr. Mountain took exception to the method of placing the three arcs on one set of resistances, as illustrated in Fig. 2, for the reason that when one or more arcs were stopped, the current passing through the remaining arc would be interfered with; but, as explained in the paper, when this arrangement of resistances was adopted, only one arc was used at a time.

Mr. Newitt asked for particulars of an arrangement in which the electric arc is directed by the aid of a powerful electro-magnet, and in connection with which the writer had a lively recollection of an experiment conducted by Mr. Newitt and himself some five years ago. This system, known as the "deflected arc system," was the invention of Dr. Zerener, of Berlin, the sole right of use in this country being vested in Mr. T. Scott Anderson, of Sheffield, and was one in which both poles of the dynamo were brought to the welding apparatus (not as in Benardo's system, one to the article to be welded), and where the apparatus was not held by the workman but was suspended over the work. Not having seen this particular development of the process of electric welding in actual operation, the writer has had no opportunity of forming any opinion as to its general utility; but, in answer to enquiries, Mr. Anderson replied as follows:—

The arc is deflected by a pair of magnets between which the carbons are regulated, and by means of a small screw the arc can be twisted into any required direction. In the large lamps, say from 100 ampères upwards, the regulation is performed by a small automatic arrangement, so that the feed of the carbons is kept regular. In the small lamps which are used for brazing and soldering the regulation is performed by hand. The larger lamps are used for much the same purposes as the Benardo's system, viz., for repairing castings machinery, etc., and there is not the slightest chance of burning the metal. Again, for the manufacture of steel barrels for carrying petroleum, etc., we find with our system there is not the slightest difficulty, and we have already two plants working for this purpose alone, each of 800 ampères capacity, and we are turning out a large quantity of these barrels every day. We have also done some good welding

in tubes and pipe combinations, and here again we find that with our perfect regulation there is no chance of burning the metal. The lamp is suspended over the work exactly as an arc lamp would be; the distance from the work must be judged, and then the current is turned on, and the flame adjusted at will. I may instance one work in particular, viz., the cycle trade, in which it has long been felt that something was wanting for brazing the parts, and we have carried out a large number of experiments in this line. Two plants are working, and with 80 volts and 30 ampères one plant is doing 2,000 brazes per week with one man. For copper and brass tubes we have done excellent work both with longitudinal welds and ordinary brazing. This work is most economical, and is a great improvement on the old method. Another success is in seam welds, and we have done these on all size plates down to $\frac{3}{32}$ and up to $\frac{3}{4}$ inch thick; this work is indeed one of the finest examples of the deflected arc. Of course the reason for the success is the fact of being able to spread the heat over a given area, and to regulate the amount of heat concentrated upon any one spot. In ornamental copper and brass work $\frac{1}{16}$ inch thick we have made perfect welds, and this is, as you know, a difficult matter.

Mr. Newitt referred to the application of the electric arc to boring holes in metal plates as of doubtful utility (but with the redeeming feature that no doubt the experiment was very pretty), and gave certain erroneous figures as to time, and calculations in regard to cost of this operation, which clearly showed that he had not understood the writer's meaning; for although the tube was in the electric shop eight hours (from 8 a.m. until 4 p.m.) it was clearly stated on page 175, that when working, the holes were pierced at the rate of between two and three per minute. The actual time, however, taken to simply pierce the holes, and which also represented the time that full current was on, was exactly five seconds per hole, and the rate given in the paper, viz., two to three holes per minute, also included the time of moving the carbon from hole to hole. The current required was 300 ampères at 70 volts, equivalent to 21,000 watts or 21 units, which at the rate of 6d. per hour per unit given by Mr. Newitt represented a plant cost of 10s. 6d. per hour. Now, even assuming that full current was on for one-third of a minute per hole, the total time for which full current would be required to pierce all the holes would be 101 minutes or 1·69 hours, which at 10s. 6d. per hour represented a total plant cost of 17s. 9d., as against £6 given by Mr. Newitt. In reply to Mr. Newitt's question, as to whether as much as 500 ampères would be required for repairing the teeth of small cog-wheels, the writer begged to say that it did not actually require this amount of current, although it was advisable to have this amount available at the dynamo to ensure good work; and the results given by Mr. Mountain agreed with those obtained by the writer.

The PAST-PRESIDENT said he was sure he was in accord with their wishes in moving a hearty vote of thanks to Mr. Foster for his paper and the reply just made.

The vote was accorded by acclamation.

ADJOURNED DISCUSSION ON MR. S. O. KENDALL'S PAPER ON "TURRET-DECK CARGO STEAMERS.

The PAST-PRESIDENT intimated, with reference to Mr. Middlemass and his remarks at the previous meeting, which had been stopped, that they had since received a communication from him. He (the Past-President) had read it through, and he certainly thought that the way he had put his remarks now would be acceptable to the meeting. They were confined to a discussion of the turret-deck steamer.

The SECRETARY read the following communication from Mr. Middlemass:—

DEAR MR. DUCKITT,

The type of steamer I wish to compare with Mr. Kendall's turret is one not unknown to members, Mr. A. Laing contributing a sketch of a similar vessel to the *Transactions* of 1891-2. Mr. Sivewright has also (in the discussion on Messrs. Jordan and Marlborough's paper on "Types of Steamers") given us a sketch of one of these steamers. "Three-deck rule with wood main deck omitted" describes this steamer better than semi-spar-deck, as it is sometimes termed.

Plate LXVII. shows the profiles of the turret and of a single-deck steamer of the above type. Length and beam are identical, but the depth moulded of the single-decker is 24 feet 3 inches, and the load draught *ex* keel is 19 feet 7½ inches, 1½ inches more than the turret. (It was at first worked out to be 19 feet 6 inches, but partly owing to the addition of a break poop aft came out 1½ inches more.) This I do not think will greatly affect the comparison. The depth of tank is the same, and the single-decker is framed with bulb angles, so that both are on an equality for tonnage so far as these go.

The single-decker has the usual centre stanchions zig-zagged for fitting wood shifting boards when carrying grain cargoes, and, as I gathered from Capt. Petersen's remarks that these shifting boards are also required on turrets, has the weight of these been included in the light weight of turret? also the iron or other fittings necessary to secure them in position?

Comparing the two profiles, the first thing noticeable is the sheer in the single-decker and the perfectly straight line of the upper

works of the turret. Mr. Kendall's paper gives the reason for this absence of sheer, which some speakers seem to have overlooked, viz., "simplifying the construction and reducing the tonnage to a minimum;" of course the reduction of tonnage naturally follows the absence of sheer. The height of turret-deck is shown on the profile of the single-decker, so that the relative height of platform can be seen. I have omitted the hood of the turret, as it can hardly be used as a navigating platform (judging from the photos of turret steamers), and its value as an erection, considering its open after end, must be very small.

If we consider the arrangements for working the holds, etc., the single-decker is at least as good as the turret. In the first place, we have one mast and its rigging and smithwork less; we also save some winch piping. The hatches, too, are 24 by 14, and 24 by 16, as against 20 by 13 in the turret. In addition, the hatch contractors and pillars in wake of combings are, as usual, portable, which does not seem to be so feasible in the turret. This would give the single-decker an advantage where it came to the shipment of large pieces of machinery, etc., and even supposing these fixed beams in the turret hatches would not interfere with the loading of cargo, they will, I think, hinder quick discharging.

The shape of the turret sides are, however (in way of the hatches), better adapted by their shape for the stowage of grain in bulk, but it must not be forgotten that in the beam spaces under the accommodation, and also underneath the turret and harbour-decks clear of the hatches, it will be quite as difficult to stow cargo as in the single-decker. The additional hatch to No. 2 hold shown in the single-decker is also an advantage, as it can be used for discharging, which is not the case with the cross bunker hatch in the turret.

The bunkers of the single-decker may, on account of the double-deck, require a little trimming in the bridge, but she can carry 120 tons more coal than the turret without entrenching on the hold space. The forecastle also is a proper navigating platform, where a man can keep a look-out and the ship be worked from. The net register tonnage is 1,391 tons, practically the same as the turret.

I have calculated the internal capacity of the single-decker in the following manner, viz., to top of ceiling, outside of frames and top of beams for the length of the after-hold, 96 feet, and also for the cross bunker, main-hold, and fore-hold; a length of 128 feet, the deductions being tunnel recesses, tunnel, fresh water tanks, and donkey boiler recess; hatches are included, also the bridge space from the fore end of casing to bridge front, the total being 180,966 cubic feet. The fore peak is not

taken in, although it could, as the profile shows, have with every reason been added to the total. I would like Mr. Kendall to give us the turret calculated in a similar manner; hazarding the remark that the spaces alongside the accommodation under the harbour-deck will not be of much use for the stowage of any kind of cargo.

I now come to the deadweight carrying, and in this the turret, when carrying heavy cargoes, shows to a decided advantage. The deadweight of the single-decker is at 19 feet 7½ inches draught 3,700 tons, and at 19 feet 6 inches 3,660 tons. This gives the turret (assuming 3,790 tons to be correct, and Mr. Kendall can, perhaps, tell us if this weight has been carried) an advantage of 130 tons on the same draught, and as the weight of engines is the same, and the outfit can only vary 10 tons, due to the wood bridge and forecastle decks, and other small matters, it follows that a turret can be built to Lloyd's class (the difference between the turret classed by Lloyd's and the others not so built being only 5 or 6 tons of steel and iron as stated) with about 140 tons less steel and iron than this single-decked steamer.

I might point out that the turret's weight of steel and iron gives a percentage of about 17·6 of the load displacement, a result, I think, not attainable in any other class of steamer built to Lloyd's rules, 20 per cent. being difficult to obtain; and this 17·6, as there must be a still greater difference in sectional area than between the turret and Mr. Kendall's single-decker, is rather remarkable. This saving in weight is, however, a great advantage in the carriage of heavy deadweight cargoes, but, as in ballast the turret will draw 6 feet to 7 inches less than the single-decker, will not improve her behaviour in a gale of wind, and, I think, is a slight disadvantage, considering the outcry we are having *re* more water ballast in steel steamers.

With regard to the amount of reserve buoyancy given in Table A for the turret steamer, Mr. Kendall is of opinion that 60 per cent. of the turret erection should be included in this. Was the figure given in the table made out on this basis?

I would say, in conclusion, that a single-deck ship, of such a type as I have shown, while inferior to the turret for carrying heavy deadweight cargoes (due to the difference in weight of material) is, I think, as good in tonnage and cubic capacity, and is as handy for general trading, because if a 'tween deck is at any time needed it can easily be laid on the second tier of beams.

Yours faithfully,

T. MIDDLEMASS.

Mr. T. McNabb said the discussion had been abnormally lengthened, which was a proof of its importance. He did not intervene for the purpose of discussing technical points of construction involved; these had been well dealt with by shipbuilding experts, nor did he purpose saying much from a seaman's point of view. That the vessels were all Messrs. Doxford and Petersen claimed for them, he thought might be conceded in the absence of information to the contrary. As to the criticisms about absence of sheer, or the inconvenience of getting boats out and in, these seemed to him very small points. That the boats could be easily handled he would take Messrs. Doxford's word for it, though he had not seen the arrangement. There was a certain order of minds that could not accept what was new unless the novelties had originated with them, or they had been instrumental in bringing them before the public. Anything without the range of their experience was no good, and they were prepared to fall foul of such novelties—mostly showing ignorance and want of intelligence. What was the seaman critic's objection to the turret-type? He had not seen anything like it before, therefore it must be bad. He (the speaker) thought too much was made of the absence of sheer in these vessels. It was said a good sheer forward kept that end drier than it would be without, but the absence of sheer there was well compensated for by the height of the turret platform. Objection was made to this type because of an alleged unsightliness. Well, other types, the partial-awning-decker to wit, were not the most lovely things in ship creation. We could not go back to the days of Smiths, Greens, or the Dutch East Indiamen for our types, for sailing ships were practically obsolete, nor to the beautiful and majestic Inman liners, than which nothing could have been more charming to the eye of a sailor, as seen lying in the Mersey some years ago—full rigged ships with an iron tube standing up, the use of which was only known to the expert. The East Indiamen were gone, and so were the Inman clipper liners, and managers would not dream at the present time of reverting to such types particularly for tramps. *Nous avons changé tout cela maintenant.* Where was the tramp owner who wanted such vessels now? They all went for the type that would make most money on the least outlay, according to the trades they were intended for. He confessed he did not like recent developments in the form of steamers, but then he recognised that we must have the best money-making machine for making money—there was no use trying to ignore the fact that that was what steamship owners wanted, and what shipbuilders and engineers put their brains in steep to evolve, and he thought Messrs. Doxford deserved credit for bringing forth, and Capt. Petersen for

giving a full and fair trial to, the novelty. He was permitted to see the model of the first turret vessel, and while struck with the novelty—the hideousness, if one might say so—from the point of view of one who had hitherto been accustomed to other forms, he did not dare condemn it as unsuited for the purpose it was intended to fulfil, and would not do so in any case, but preferred to wait development, though from the particulars given he thought the vessel would suit the purpose very well, *i.e.*, make money as compared with current types. He was favourably impressed with Capt. Petersen's statement at Hartlepool. It was a manly one, and such as they might expect an intelligent sailor to make. As to Mr. Yeoman's wail about the well-decker, it was like "Rachel weeping for her children because they were not." Let him and those who have old shipping property, whether well or other decked, remember that no lamentations would bring back the depreciated part of their property, nor enable the 2,000 tonner of fifteen or twenty years ago to compete with the 4,000 or 10,000 tonner of modern days, having triple or quadruple engines, and 160 to 200 lbs. boiler pressure. The older vessels as money earners were out of it, not because they were well-deckers, but because they were old and small. And as regarded the vaunted well-decker of a past period, and he (the speaker) would be the last to depreciate their merits, but with all their merits he well remembered that when brought out there were Capt. Nicholsons, even in those days. If people will, or would like to retain these old vessels—and for the life of him he could not see why they should, as patriots, give them away to foreigners to compete with us in the trades they had made—why not write off so much of the capital as was represented by the reduced value, and keep the property in their own country, where it had been created and paid for; but this would cut more ways than one. Selling old shipping, whether to foreigners or to break up locally, meant fresh orders for shipbuilders, and that he could not deprecate, because of the benefits to local and national industries. The day of the 2,000 tonner was not yet quite over. He knew that in some trades these were more easily placed than the larger, but still, to be worked at all profitably, the values must be reduced by at least the depreciation or to the open market price. As, he said, the technical points had been very well discussed—strains, sections, metacentric heights, rolling, etc.—so that, if he were ever so well qualified, which he did not pretend to be, to discuss such matters in a scientific manner, though having so much to do with shipbuilding for the last twenty years, he would pass that part by, leaving it to some who, knowing no more, were always ready to pro-

nounce an opinion on any question—"fools rush in where angels fear to tread"—and would simply thank the President and Institution for permitting him to present his few disjointed and crude observations on a subject that was of importance to shipbuilders and shipowners.

Mr. G. F. MULHERION trusted the practical members of the Institution would pardon him trespassing upon their preserves; but there were one or two things he would like cleared up. The paper was entitled "Turret-deck Cargo Steamers," but only a single instance of a turret steamer was given to illustrate the subject. The one particular steamer was probably the most favourable of its type, and he believed that in the turret-deckers, as they got them larger and larger, their apparent advantages would disappear. There was also another point. Mr. Doxford showed the profile of a partial-awning-decker, and compared it with the profile of the turret vessel, but the latter was like one of the characters in a comic opera, turn it round and there was very little to be seen. The turret-decker, taken all through, showed a height to weather deck of about 29 feet 8 inches, and the partial-awning-decker 34 feet 10 inches (5 feet 2 inches higher), and the whole of this extra height, together with the excess on each side, was good surplus buoyancy. [Mr. Mulherion illustrated his point by a chalk drawing.] There was another thing in comparing the tonnages: one was struck with the difference in the capacities as compared with the tonnages. In all vessels the under-deck tonnage was taken to be a measure of the internal capacity, but in the vessels compared the turret-decker gave 131 cubic feet capacity for bulk cargoes per ton of the under-deck tonnage, and the partial-awning-decker showed only 123 cubic feet, and naturally the question arose "Why was this discrepancy?" He would like to know how the tonnage ordinates of the turret-deck vessels were obtained? They all remembered the attempts to save tonnage with the sloping floors, where the first ordinate was taken from the top of the floor and they saved so much space. Was it not possible there was a saving through some similar cause? For instance, might not the length of the ordinate nearest the so-called harbour-deck be taken within the turret and so show a reduced tonnage? The point, however, which struck him most was the exceedingly small freeboard of 4·8 to the harbour-deck. Lloyd's freeboard tables were based on the surplus buoyancy. Table A was for flush-deck vessels, Table B for spar-deckers, Table C for awning-deckers, and Table D for sailing ships. There should, he thought, be a Table E for turret-deck steamers. The existing freeboard tables were, he thought, only designed to take notice of types up to the time of their publication,

and this new type should be arranged for in Table E. Here they found a turret-deck vessel with an equipped weight of 1,440 tons carrying a deadweight of 3,790 tons, whereas after all the efforts of their shipbuilders in the building up of modern types of vessels they were only able to carry, according to the paper, 3,650 tons on an equipped weight of 1,580 tons. Did that suggest their efforts at shipbuilding were futile and without results, or did it suggest an undue advantage was being given to turret-deck steamers?

The following communication from Mr. A. E. Muir, which the Secretary stated had been seen by the author of the paper, was taken as read :—

DEAR MR. DUCKITT,

Whilst Mr. Kendall is to be congratulated for the able manner in which he has dealt with the various points of turret steamers, I would like to make a few remarks on the figures given in the paper. The strength of the turret over the other types compared, cannot, I think, be disputed, but I hold that the comparisons are unfair, insomuch that the turret is classed with a different registry, viz., Veritas and British Corporation against Lloyd's for the other steamers. The turret steamer built to Lloyd's would require a much larger weight of material; for instance, a higher tank without increasing the strength of bottom girder. I venture to suggest that if Mr. Kendall either put single-deck and partial-awning-deck ships to British Corporation and Veritas, or *vice versa*, the turret to Lloyd's, then show comparisons of deadweights, strengths, etc.

Deadweight.—Having gone into Mr. Kendall's paper to a considerable extent, and compared the types with vessels already built, I notice some very large differences in the figures given in Table A of the paper which I would like him to explain. With reference to deadweight in the turret steamer I notice 3,790 tons is given, and also 3,650 tons given as deadweight for the partial-awning-deck, both of which I think should be reduced by about 100 tons, which will materially alter the ratio of deadweight to load displacement; also ratio of net register to deadweight cargo and ratio of case and bulk cargoes. Assuming my calculation of deadweight to be correct, instead of the partial-awning-deck ratio of deadweight to displacement being 69·8 per cent. it is 67·9 per cent., and the turret being now 70·55 per cent. instead of 72·5 per cent. as given by Mr. Kendall, so that now the increase of turret over partial-awning-deck is only 2·65 per cent., the same as the single-deck

ratio of deadweight to displacement. I may also observe that Mr. Kendall assumes close bulwarks on the single-deck ship, as against open rails in the turret. Could not open rails be fitted with advantage to the single-deck vessel, and by that means lighten the ship to compare with the turret?

Tonnage.—As I have tried a comparison with several known steamers I fail to find out how Mr. Kendall works his tonnage in single and partial-awning-deck to make the under-deck and gross tonnages of both types so large. I think a reduction might be made in the partial-awning-deck under-deck tonnage by something like 20 tons, and in the single-deck ship by about 33 tons, and also by allowing an open bridge in the single-deck vessel the gross tonnage may be reduced by about 100 tons, and the net would then be 70 tons less than that shown in the paper, and thereby decreasing the ratio of net register to deadweight cargo by about 3 per cent. Furthermore, if the single-deck was allowed an open forecastle and sunk crew space, as in the turret, also having an open bridge, the gross tonnage might be still further reduced by 58 tons, and the net reduced 40 tons, and altering the ratio of net register to deadweight 1¼ per cent. It will, no doubt, be said that doing this will reduce the capacity; that is granted, but the capacity is not reduced to the same extent as the tonnage. So far as I can make out the turret-deck steamers' tonnages are correct on the same basis as my figures are all taken at.

Cargo Capacity.—Again, referring to capacities, I have made the turret-deck bulk capacity some 9,000 cubic feet less than shown in the paper, and in the case of the single-deck 2,000 less, and in the partial-awning-deck 2,000 less. As tonnage is a measurement of capacity, I cannot see how the turret can have so large a capacity as given in the paper when the under-deck tonnage is so small. Perhaps Mr. Kendall will explain this. Making a summary of the preceding, it will be observed that the turret cannot claim all the advantages shown in the paper, and I think the writer has given the single-deck ship an unnecessary shelving, as by comparing my figures it will be seen that the single-deck steamer compares favourably with the turret in respect to tonnage and capacity.

Yours faithfully,

A. E. Muir.

MR. KENDALL'S REPLY.

Mr. S. O. KENDALL remarked, in proceeding to reply to the speakers on his paper, that it had been said the discussion was abnormally long. Well, if it had been extraordinarily long, it necessarily followed that the reply should be at some length; but he had tried to contract it as much as possible, and still to cover all the essential points raised in the discussion. He must crave their indulgence if he should happen to take up a good deal of their time. Before replying to the various remarks and criticisms which had been made in the course of the discussion on this paper, he thought it was due to both Messrs. Doxford and himself to make a personal explanation as to the origin of the paper. From the remarks of some of the speakers, there would appear to be an impression that this paper was inspired by Messrs. Doxford and written at their suggestion. He was sorry that this impression should have arisen, and he wished to state that it was entirely erroneous, and that Messrs. Doxford had nothing whatever to do with the paper. He chose the subject of turret steamers on account of the general interest which he thought it would have, and because it seemed to him extremely fitting that it should form the subject of a discussion before this Institution, as the turret vessel might be said to be a product of the North-East Coast. After asking the consent of Messrs. Doxford, he had no further communication with them on the subject until the completion of the paper in its present form. The particulars as to deadweight, given in Table A, page 223, were obtained from actual draughts taken for another purpose some twelve months ago from the S.S. "Turret Bell" (the original of the vessel whose particulars were given), and the displacement scale from which the weights were taken, and all the rest of the figures were from independent calculations, so that none of the results given for the turret steamer were from Messrs. Doxford's unsupported figures. He felt it necessary to make this explanation, because he thought for a paper of this kind to have any value at all it should be written without bias or prejudice in either direction, and this was what he had tried to do, though with only moderate success he was afraid, for he repeatedly met with charges of unfairness to the ordinary type of vessel in the course of the discussion, and he wished to state that if it could be shown how better results could be obtained than those given in Table A, no one would be more ready to acknowledge that improvement than himself, no matter what the type might be.

Generally speaking, the remarks might be divided into two sections. One in which the peculiarities and defects of the turret steamer were criticised, and the other in which an effort was made to discount the advantages of the turret steamer by showing:—First, that an inferior type of vessel had been chosen for the purpose of comparison; and, secondly, that the chosen types had been unfairly treated. Now, as the latter criticism more particularly affected the impartiality and consequently the value of the whole paper, he proposed to deal with it first. As regarded the type of vessel chosen for comparison with the turret, there seemed to have been a pretty general idea among some of the speakers that if they had had the choice of the types and the working out of the figures they could have produced better results. Mr. Courtier-Dutton regretted that he should have taken that hybrid type of vessel, the part-awning-decker, for comparison. Capt. Nicholson, on the other hand, thought that the part-awning-decker was the only vessel worthy of consideration, and that the single-deck steamer was entirely obsolete, and was discarded in the early seventies. By the way, this latter gentleman had fallen into a curious error in this respect. If he would show him or give him particulars of a vessel of 23 feet 6 inches depth moulded, built either in the early seventies or the early eighties, with only a single deck, he would be very much obliged to him There was no doubt that the single-deck vessel to which he referred was a vessel of such dimensions as only to require one laid deck according to the rules; but the vessel under consideration was not of this type at all, she required, according to the rules, two complete laid decks, but as the second deck was not needed, it was no use putting it in, if the strength could be compensated for otherwise. But even accepting the single-decker and part-awning-decker for comparison with the turret, it had been maintained by several speakers that they had been unfairly treated. Now, he thought he could show clearly that this was not the case, and that the complaints of unfairness were for the most part founded on erroneous assumptions. For instance, Mr. Thompson said that from the section shown in Plate LVIII., the single-deck steamer had a tank 2 inches deeper than the turret, and that this reduced the capacity of the former accordingly. This was not the case at all. An examination of the section referred to would show that it was simply a sketch showing Lloyd's scantlings for the purpose of comparison of strength; it had nothing to do with the general design, and in calculating the capacities and tonnage the same depth of tank and of frames was taken in all three cases. Again, Mr. Thompson said that the vessels he had chosen were

very ordinary cargo vessels, and that the more modern types would have given better results. He would have been very pleased to have had some information regarding these modern types, and he regretted that Mr. Thompson did not enlighten them on the subject.

In order to test the accuracy of the figures given in Table A, page 223, he compared his with those which Messrs. J. L. Thompson kindly placed at the disposal of Messrs. Jordan and Marlborough in their valuable paper read before the Institution two years ago. In that paper the part-awning-deck steamer was unquestionably shown as the best deadweight carrier and the least costly of any type of cargo steamer. Now, all the vessels given in this paper had ·78 displacement coefficient, whereas he had a coefficient of ·795; reducing this coefficient to ·78 would take exactly 100 tons off the displacement. Now, even if he took the whole of this 100 tons from the deadweight without allowing anything for the reduction in the weight of hull due to the finer model, he found that he gave the part-awning-decker 3,550 tons deadweight, while in the paper referred to this type of steamer was only allowed 3,500 tons, and at the same time the net tonnage and the cargo capacity almost coincided in each case, so that there did not appear to be much unfairness there.

As regarded the single-deck steamer, on comparing her in the same way with the three-deck steamers given in Messrs. Jordan and Marlborough's paper, he found that he credited the vessel with 100 tons more deadweight, about 20 tons less net register, and 2,500 cubic feet more cargo capacity. Even allowing for the difference caused by the absence of the 'tween decks, he thought it would be generally admitted that if his figures were so much better than those of Mr. Thompson's esteemed firm, they must be very good indeed, and not so ordinary as he supposed. Another point he might mention in passing was the indicated horse-power, although this had nothing to do with the turret steamer. Mr. Thompson said 1,050 indicated horse-power was too much for 9 knots, but he found that the vessels he had quoted above took 1,150 to drive 9½ with 100 tons less displacement, so that he did not think 1,050 indicated horse-power could be far out.

Then Mr. Thompson had several grievances against the sketches shown in Plate LVI. For the most part they were mere matters of detail and arrangement, and would have no appreciable effect on the figures given in Table A. For instance, he said the main mast could be placed between the two after-hatches, and the mizen mast be saved. Quite so, but what was to prevent the same arrangement being carried out in the turret. It was simply a matter of option, and it had evidently been found preferable

to fit the three masts, for there was nothing whatever to prevent them saving the third mast if there was anything in it. Then Mr. Thompson thought better results would follow by putting the cabins in a sunk poop aft. That might be, but one result would be that in bad weather the difficulty in getting back and forwards would be very great, and if this arrangement were adopted he would say, why not go the whole hog at once, and make her an awning-deck ship? One objection was that the vessel would lose her 180 or 200 feet forecastle which was so useful in keeping the tonnage down, but it was curious to think that if any man twenty years ago had proposed to take an awning-deck ship and cut away the main deck for about 80 feet in the after-hold and there drop the awning-deck down about 3 feet 6 inches, and had claimed to have improved the original design by doing so, he would have been laughed to scorn, yet this was what they had come to in this part-awning-decker with a sunk poop. He did not say this in disparagement of the type, but merely to show how, by gradual stages, a type could be evolved, which would have been treated with derision had it been originally introduced in its ultimate form.

Another gentleman, Mr. Middlemass, seemed particularly grieved at the treatment of the single-decked vessel. With regard to his remarks, he must say that he was very sorry that he could not make better use of the time at his disposal than to repeat in a great measure the details of Mr. Thompson's criticism, which he no doubt heard at Hartlepool. There was that third mast—they had that before; then the depth of the double bottom and the depth of the frames in the turret being $1\frac{1}{2}$ inches deeper than the ordinary vessel—they had that before; the after wheel house, with 3 feet too much on the length of it, and, in addition, a half round on the edge of the sheer strake. These things struck Mr. Middlemass very forcibly as a great injustice, but with marvellous facility he made a change of front, and suggested that the vessel had been treated too favourably, and that the hold beams and web frames would require to be increased to meet Lloyd's requirements. In the case of this comparison Lloyd's rules had nothing to do with the matter beyond furnishing a standard for comparing the longitudinal strength. The paper was prepared on the basis that the ordinary vessel was entitled to any arrangement which was applicable to the two types, and he thought it would be admitted that the ordinary vessel might be allowed the same hold stiffening as the turret, except for the advantage which the rounded gunwale, and the absence of sheer gave the latter.

In passing, he might notice the curious contradictions which occurred in some of the remarks. He had mentioned the differences of opinion as to type, and in addition, on the one hand, it was said that the ordinary vessel had been unfairly treated, loaded down with an extra mast and three feet of deck house, etc.; and, on the other hand, they had the communication of Mr. Muir asserting that 100 tons should come off the deadweight; and, again, some of the speakers had complained of the unfairness of comparing the turret with vessels classed at Lloyd's, and others that the ordinary vessels in Table A would require increases to make them up to Lloyd's rules. As to the facts of this latter point he did not think it necessary to do more than refer these gentlemen to the remarks of Mr. Doxford as to the extra weight in the turret vessel classed at Lloyd's. Mr. Middlemass also asked, Why should not the ordinary vessel have flanged floors, bulb angle frames, and all the advantages of modern improvements? A little consideration would have shown this gentleman the reason. As he said before, the scantlings shown in Plate LVIII. were simply those of the rules taken from the tables for the purpose of comparing the longitudinal strength, and for obvious reasons he did not think it desirable to make any deviation from the rule scantling; but he could assure Mr. Middlemass that the capacities were calculated with a 38 inch tank. The tonnage was calculated with frames the same depth as the turret, and in calculating the weight of the single-deck vessel, exactly the same structural arrangements were allowed for in both vessels. Where material was flanged in the turret it was flanged in the single-deck vessel, and the half-round moulding on the upper edge of the sheer strake was not included in the weight. He had no doubt it would be a satisfaction to Mr. Middlemass to learn this, but he would have much preferred if he had stuck to the figures in Table A, instead of quibbling over small details. If he considered that the allowance of deadweight was a fair figure for the type, then he thought he might have let these small things alone, and he suggested that had he confined himself to the essential features of the design, and introduced the semi-spar-decker at first, his remarks would have been very interesting. Mr. Middlemass also said the single-deck vessel was an obsolete type. Now, he would not have expected him to fall into this error, but what surprised him was that the very type which he proposed to substitute was practically the same as the single-decker, for what was a semi-spar-deck vessel but a single-deck vessel with a tier of beams. But why fit a tier of beams if they did not want them, and could get the strength in other ways? The turret vessel had not got a second tier of beams, so in the case of the semi-spar-decker

they compensated for these beams with strong hold beams and web frames, and then, according to Mr. Middlemass, they had an obsolete ship, extinct in the seventies or eighties. Probably, had he called the type a semi-three-decker, so great was the power of a name, that she would have been considered a new thing.

He would like to drop a word of warning, in passing, to those owners who were going in for vessels with a tier of main deck beams unprotected by a laid deck. The experience he had had with older vessels where this had been done, was that the deterioration and damage was so great from the trimming of coal and other bulk cargoes past the beams that in a few years these beams and also the unprotected stringer and tie plates required to be renewed or very largely repaired.

On looking over the figures given in Table A, in the light of the criticism, he did not think they were very far from correct, but he quite agreed that the tonnage of the single-deck steamer could be considerably reduced, even as low as 1,380 tons net register, by making an open forecastle, putting the crew below the upper deck, and opening up the bridge, but at what a cost in the efficiency of the vessel. These erections were assumed to be closed in in order to get the full benefit for freeboard, but not only this, they were of vital importance to the stability, and if left open, instead of being an aid they would be most inimical to her safety, and she would have a very poor curve of stability without erections; indeed the curve would vanish at 76 degrees with as much as 2·75 G.M., but there was no doubt it was quite possible to get the net tonnage of the single-deck vessel down as low as that of the turret and still have almost as much capacity; but there was this difference, that whereas the turret attained this without any sacrifice of efficiency as regarded stability and reserve buoyancy, the ordinary low freeboard vessel made considerable sacrifices in both these qualities in effecting the desired economy in tonnage. It was wonderful the results which could be obtained with a little judicious dodging in the erections. Both Mr. Thompson and Mr. Sivewright had mentioned vessels with a large cubic capacity and small net tonnage. The latter gentleman remarked that this end was attained by building the vessel with deep frames and "other arrangements." Now, there seemed to be a good deal of reticence with regard to these other arrangements. He would not pretend to say what they were, but he knew one way was to construct a vessel with as small an under-deck tonnage as possible, and then put on a good sized poop, bridge, or forecastle; any or all of these erections as might be desired. Then by placing a bulkhead at the fore end of the poop and leaving a hole in it, a solid bulk-

head at the fore end of the bridge, and a bulkhead with holes in it at the after end, some curious results could be obtained, for when the vessel was measured for freeboard these erections went in as surplus buoyancy; when she was measured for tonnage they became open spaces, and consequently were not included in the tonnage; and when she was measured for cargo capacity these erections became efficient closed in spaces, suitable for carrying dry and perishable goods to all parts of the world. In this way some marvellous results could be obtained in the ratio of capacity to net register, but the question was, were these spaces fit for dry and perishable goods if left with such openings as to warrant their being excluded from the tonnage? Were they not simply covered-in spaces for deck cargo? He had no doubt ample provision was made for closing up these openings with portable plates; in fact he would not give much for the safety of the vessel if they were not; but he thought, in the interests of underwriters, charterers, and in fairness to other vessels, open erections of such a character as to be excluded from the tonnage should be noted as such in the register. This arrangement of erections was a distinct loss where vessels were running with deadweight cargoes of even moderate density, for every foot of open erection meant so much off the deadweight, so much on the top hamper of the vessel, and so much on the first cost. He would also like to point out that such erections are always included in the Suez canal tonnage, and also that if cargo is carried in these spaces, dues, etc., could be claimed on the tonnage of them if they were known to be omitted from the tonnage. He did not suggest that a shipbuilder or owner was in the least to blame for adopting such methods of reducing tonnage. The law, as at present constituted, allowed this anomaly, and it was only another instance of its inconsistencies; but he thought the difficulty would be removed by marking these erections as "open" in the register.

He now proposed to reply briefly to the criticisms on the turret steamer, which had not yet been answered, and he must thank Capt. Petersen and Mr. C. D. Doxford for having considerably lightened the task, for without their valuable remarks he could not possibly, in the time at his disposal, have covered all the remarks in the discussion.

Mr. Courtier-Dutton, he was pleased to find, was in pretty general agreement as to the technical merits of the turret type, and he quite endorsed his opinion of source of danger to stability of bridges and erections not fully closed in. Capt. Nicholson's remarks had, he thought, been pretty fully and satisfactorily dealt with by Capt. Petersen and Mr. Doxford, and he would only refer to one or two points. He said the

turret's capacity for case cargo would not be 48·7 cubic feet per ton, b more like 45 cubic feet: this would mean that the figure he gave w 13,000 cubic feet too much, and he wondered if Capt. Nicholson expect the meeting to take his mental calculations seriously. He could ass him these results were not arrived at by rule of thumb, but by care calculation. Again, he asked, was any deductions made for the brok stowage at the round of the turret gunwale. Certainly not; he would more think of deducting anything there than he would of making a ded tion at the rounded bilge of a vessel with ordinary floors. Then Ca Nicholson said that bulk cargo was always trimmed up between the bea He did not believe that bulk cargo could be got within an average dista of 6 inches of the deck, and he did not believe he (Capt. Nicholson) h ever seen a cargo so trimmed. As a matter of fact the single-decker co u not carry bulk grain up to the deck for the regulations would require th upper 25 per cent. to be bagged, unless the hatches were increased in siz to, he believed, 2 per cent. of hold capacity. What he (Mr. Kendall) wished to point out was the superiority of the section of the turret for allowing grain to trim down between the beams as compared with a flat deck, and a hatch coaming coming down below the deck, effectually stopping any such movement. Capt. Nicholson was much amused at the idea of the turret vessel carrying deck cargoes. Well, they had repeatedly done it in a satisfactory manner, and there was nothing amusing in that. At the meeting of March 12th he showed a photo of one of these deck cargoes loaded up; this was now reproduced in Plate LXVIII., and gave a good idea of the arrangement. This gentleman as well as others thought he claimed an exclusive advantage in stability for the turret steamer, owing to her light rig. He did nothing of the kind; what he did say was that a vessel with light rig and little top hamper did not require the reserve of stability which a heavily rigged steamer or sailing vessel did, irrespective of type.

Capt. Nicholson's remarks about the sea qualities of the turret would have been more effective had they been uttered two and a half years ago; in fact they bore a strong resemblance to the remarks of the gentleman who prophesied disaster on the first voyage of the turret. He at least had then the excuse that the type was untried, but Capt. Nicholson's prophecies after the event were contrary to the facts of the case. So he said there was something wrong with the facts! If a man could not take the official log books of a vessel then there was nothing more to be said. It really seemed to him, with all due respect to Capt. Nicholson, that the key-note of his remarks on this point of seaworthiness was prejudice. Capt. Nicholson's estimate of coal at 51 to 55 cubic feet per ton was entirely

out of it. The lightest coal ever shipped did not exceed 48 cubic feet per ton, and this was a very liberal estimate.

Mr. Watson, the next speaker, seemed also to be prejudiced. It was astonishing the difficulty of impressing people with the fact that the turret below water was the same as any ordinary full tramp. The charge "wall-sided and flat-bottomed" might be brought against almost all full cargo steamers. Perhaps a voyage or two in a turret would be the most convincing argument for this gentleman which could be brought forward. He would be pleased to give Capt. Watson an explanation of the stability curves shown in Plate LIX., but he thought that was hardly the place for an explanation of the elements of stability.

He thought Mr. Thompson must have misunderstood Capt. Petersen with regard to seas washing over the turret-deck. He found no such statement in his remarks as Mr. Thompson attributed to him.

Mr. Arnison's estimate of the reduction in the longitudinal strains of the turret was overstated, he thought. The reduction in weight of vessel at ends was quite inappreciable compared with the reduction in weight of cargo; but when an ordinary vessel was carrying deadweight cargoes not filling the holds, then the weight could be reduced in the forward and after-holds of an ordinary vessel, and the curve of loading would be more practically the same as the turret vessel.

He must thank Mr. McGlashan for his straightforward and clear criticism. He had not confused the issues with unimportant details. His great difficulty appeared to be the apparent anomaly in the turret of a higher capacity and lower net register than ordinary type. He had already shown how this came about, and how the ratio in an ordinary vessel might be increased. He also said it was almost impossible to have a high capacity and a low net register. Mr. McGlashan thought the impossible had been achieved in the turret vessel, but a moment's consideration would show that, although the turret had a low tonnage, she had only a medium capacity.

Mr. Fothergill said there was more than one steamer with cubic capacity, measurement, and draught for deadweight carried, equal to the turret steamer. There was not the slightest doubt about that. He had stated that on a capacity basis there were many vessels superior to the turret; the point of comparison was the ratio of deadweight to displacement, and on this basis he did not think there was any type of vessel which could compare to the turret. The same remark applied to the ratio of deadweight to net tonnage for vessels of similar dimensions, though in small vessels the net tonnage was so erratic on account of the

propelling space deduction that some very curious results often occurred, as already pointed out by Mr. Thompson. He quite agreed with Mr. Fothergill that the appearance of sheer on an ordinary vessel led to a misconception as to its value. Certainly sheer enabled a vessel to lift readily to a head sea, but there was not much use in that if the water came over in the waist of the vessel at a point some 10 or 12 feet below the level of the forecastle head, and this was the weak point where most vessels shipped seas; but with the turret, if the sea did not come over the forecastle head, which from all accounts it did not do, it had very little chance of coming on the turret-deck further aft.

Mr. Greenhow was very enthusiastic as to the commercial advantages of the turret type. He had no doubt his confidence was quite justified; at least one firm of shipowners had found it so to their satisfaction, but he had preferred to stick to the technical side of the question, leaving the commercial aspect to those better fitted to deal with it.

He quite appreciated the value of Mr. Jordan's remarks as to the varying ratios with different sizes of vessels, but he wished to point out that an extended comparison only confused the issues by presenting a mass of figures of secondary importance which could not readily be grasped, and on the other hand involved a great amount of extra work. The turret chosen was one of average dimensions, and the results were about an average. In larger vessels a poorer comparison might result, and in smaller ones a better one would be obtained. He did not consider the spar and awning-deck types as applicable in this case for comparison; they were capacity vessels pure and simple, and the turret chosen was a deadweight boat. Mr. Doxford was confident that a capacity turret vessel could be constructed, but it would be premature to discuss such a vessel until it was put into practical shape.

Regarding the communication of Mr. Middlemass, he was sorry, as he said before, that he did not introduce his semi-spar-decker earlier at the Sunderland meeting. With regard to his results, though Mr. Middlemass did not say so, there was no doubt that they were obtained by the process to which he before alluded to. The capacity, he said, included a considerable quantity in the bridge, but there was no tonnage in this erection; by a judicious arrangement of portable plates this space was blocked up or left open according as surplus buoyancy, tonnage, or cargo capacity was under consideration. He dared say this change of front was comparatively easy when the matters were dealt with at different times, but in a discussion like this all three were considered at once, and it was rather difficult to say in one breath that a certain space was closed in, that it was

open space not available for dry and perishable goods, that it was efficient closed-in cargo space and suitable for any class of cargo. At any rate he (Mr. Kendall) would not call it judicious to do so. This, however, was what Mr. Middlemass had done, for by no other way could he get the ratio between capacity and tonnage which he had. He might have got much better results by extending the bridge further forward—the further forward the better for the figures. Mr. Middlemass had taken his capacity to the top of the beams, so the results obtained could be valued accordingly, but he wished he had given the case capacity, as he would have found the second tier of beams somewhat in the way.

Mr. Middlemass wrote to him privately and asked him, among other things, if the grain shifting boards were included in the equipped weight. He assured him they were, and he failed to understand why he should repeat the question. He had seen his sketch showing a section of the turret vessel with the accommodation in it. Well, he must say that Mr. Middlemass had drawn upon his imagination in drawing that accommodation, for it was not of that form at all. No one would ever dream of running up a bulkhead perpendicularly to meet the sides of the turrets as he had done. It would be impracticable.

Mr. Muir in saying that 100 tons should come off the deadweight of the turret evidently overlooked the fact that she was an actual vessel and had carried the deadweight named. As for the part-awning-decker, the original from which the figures were calculated was one of the very latest productions of this type, of almost exactly the same dimensions and draught, so the deadweight given might be relied upon. He agreed with Mr. Muir that the tonnage of the single-decker might be reduced as he suggested, but, as he said before, only if other important qualities were ignored. He was afraid Mr. Muir was out of it with his capacities. If his figures were correct for the turret, then the sister ship of the original vessel would not have carried the amount of cargo which she had repeatedly loaded, and this was a far better guide than any figures.

There were one or two remarks he would like to make in connection with Mr. Mulherion's observations. He pointed out the difference in the shape of the turret steamer and the part-awning-deck steamer at the fore end. That was quite true. The part-awning-deck steamer had very much more buoyancy at the fore end to lift her out of head seas than the turret steamer. But the point in question was, Did she not require more? because the turret steamer, evidently from the experience had with her at sea, had never met with any difficulty through not lifting with sufficient rapidity to the head seas. This was far better proof than any calculations

that might be made on the subject. They would at once perceive the difference between the part-awning-decker and the turret steamer. If the part-awning-decker did not lift the water came over at the lower level and flooded the navigating platform at once. With the turret steamer it was immaterial; she might only rise to a limited extent, but there was no harm done, the harbour-decks at the side were flooded, and afterwards the water fell off at each side; but there was no danger of the water coming on board at the central part, the most important part of the vessel. Another point, which had an important bearing on the sea qualities of the turret type, was, that in driving into a head sea and taking water over the harbour-deck at the fore end, as a general rule it would be in such free communication with the surrounding sea that there would be no weight of water on the deck at all to prevent her rising, like a deadweight of water filling up the well or bulwarks of an ordinary vessel would. This fact is not, as a rule, fully appreciated, but, nevertheless, it is one of the first principles of hydrostatics. He (Mr. Mulherion) remarked upon the discrepancy of the turret steamer tonnage and the cargo capacity. There was nothing very extraordinary about this in reality, for he had shown that a single-deck steamer could give similar results. If they only went about with the object of reducing tonnage, they could get quite as good results as in the turret steamers, but in arriving at that they forgot other things. Regarding the tonnage measurements at the harbour-deck there might be something in that, but what there was was very slight indeed. The measurement of the outer ordinate was not such as was assumed in the sketch, but measured as far out as the flat of the deck runs before the round came in. Certainly there was a slight gain in tonnage at that point, but it was quite immaterial. There was one other remark about the freeboard of this vessel. He had been asked if in the freeboard assigned to the vessel he had chosen, 60 per cent. of the buoyancy of the turret erection was taken as available buoyancy. Well, he did not know anything about that, he simply had taken the statutory freeboard as it was assigned to the vessel; but he could say that this question of the freeboard of the turret steamers had received the full consideration of all the societies which were appointed by the Board of Trade for the assigning of freeboards. It might not be generally known, but there was a commission of all these societies, and they discussed this very point. The result arrived at might be considered by some too favourable to the turret steamer; it might be considered by others very unfavourable to the type; but the amount that was given was 40 per cent. of the buoyancy of the turret erection considered available for freeboard purposes. He believed that this decision

was only to apply temporarily and that at the end of a certain period, when sufficient experience had been gained as to the sea qualities of turret vessels, the matter would be reconsidered.

In conclusion, he begged to thank those members who had contributed to the discussion. Of course there were differences of opinion, and always would be on such a subject as this, but it was only by discussion that the correct value of an arrangement could be arrived at, and the conclusion he came to was that the best results would be given by each type in the particular trade for which it was suited, or, briefly, each to his trade. But for an all-round tramp cargo steamer with a large deadweight, small tonnage, and medium cargo capacity, and easy facilities for the trimming of bulk of grain cargoes, he thought that the turret-deck cargo steamer was at present superior to any other type intended for similar purposes.

The PAST-PRESIDENT said he had very great pleasure in moving from the chair that the best thanks of this Institution be given to Mr. Kendall for his paper on the turret-deck steamers, and also for his admirable reply on the discussion. The benefit of the papers put before them was much enhanced by the discussion and the reply, and in both these respects this paper stood very high indeed.

The motion was put to the meeting, and carried by acclamation.

ADJOURNED DISCUSSION ON MR. G. H. BAINES'S PAPER ON "THE METRIC SYSTEM OF WEIGHTS AND MEASURES."

The SECRETARY (Mr. Duckitt) said that at the last general meeting Col. A. Robson gave notice that, in connection with Mr. Baines's paper on "The Metric System of Weights and Measures," he would at the present meeting move the following resolution:—

"That this Institution, observing that a Select Committee of the House of Commons is considering our system of weights and measures, and whether any change should be adopted, is strongly of opinion that the early adoption of the decimal and metric system would be a national benefit to the people of the United Kingdom.

"It believes that it would greatly promote the expansion of our foreign trade, and also simplify business transactions at home.

"The Institution is of opinion that the transition can be effected with very little hardship to traders, manufacturers, and the public generally, and that by conferences in various parts of the country any difficulties in special trades could be easily adjusted.

"That a copy of this resolution be sent to Sir Henry Roscoe, chairman of the Select Committee."

The PAST-PRESIDENT said the Council at its last meeting had considered the terms of the proposed resolution, and desired it altered to read as follows:—

"That this Institution, learning that a Select Committee of the House of Commons is considering our system of weights and measures, is strongly of opinion that the early adoption of the metric system would be a national benefit, and would greatly promote the expansion of our foreign trade, and also simplify business transactions at home.

"That a copy of this resolution be sent to Sir Henry Roscoe, chairman of the Select Committee."

With Mr. Baines's sanction, he should move that this be substituted for the motion sent in by Col. Robson.

Mr. G. H. BAINES said he thought the resolution as drafted by Col. Robson was of a practical character, yet the Council in their wisdom thought the assertion that change from the present to the metric system would not inflict much hardship upon the country would be open to question, and so they had modified it. On behalf of Col. Robson and himself he begged to accept the resolution as amended.

Mr. T. MUDD said no one, he thought, had had better opportunity than he had of knowing the amount of labour and pains that Mr. Baines had expended in getting up his paper on the metrical system, and in endeavouring to put the subject fully and acceptably before the Institution, therefore he thought no one more fully appreciated the desirability of giving their thanks as an Institution to Mr. Baines for his trouble; but at the same time he would make no further remark on that head, as it would come better from some one not so intimately connected with Mr. Baines as he was. They might discuss the question of the adoption of the metrical system from various points of view. They might discuss it from the theoretical point of view, and from the practical, as engineers and shipbuilders. There was also another way of looking at it which, perhaps, some politicians might desire to adopt, and that was what one might call the sentimental point of view, in which it is asked whether it is not beneath the dignity of a nation calling itself the first engineering nation of the world to adopt a system of weights and measures originated elsewhere. It seemed to him that perhaps their national pride had stood in the way of their adoption of the metrical system for something like a century; and although it might not be wise to give up their national pride, it did seem to him to be high time they gave up feeling that all the brains in creation were concentrated upon this little island. He thought it was part of the duty of an Institution of this kind to assimilate the good work that was done elsewhere, and accord a proper meed of credit to great achievements wherever they might have originated. He would like to say, too, that if the most sensitive amongst them should feel some humiliation in this suggested adoption of a system of weights and measures originated outside their own country, they had at least one consolation, and that was the consolation that the practical man had over the theorist. He took it that the business of the theorist was mainly to devise and sharpen the tools for the practical man to use. The practical man was far too much engaged in doing practical work to spend time whetting his knife, and they in England had been so busy turning out actual engineering work

that they had not had time to study the question of making new systems of weights and measures. They turned from their work and found the thing done for them. Surely because they did not do it themselves they would not be so foolish in their chagrin as to refuse to adopt what common-sense had shown them to be a better system than they had been in the habit of using. In discussing the theoretic question they had to ask themselves, is it good in itself, and is it better than the system we now have in use? He thought no educated man would spend a quarter of an hour in looking into the metric system without having a loud-toned "yes" brought home to him with regard to both these questions. Mr. Baines had called attention to what he styled "the simple and symmetric beauty of the system." In a few words on page 288 he said:—"They decided that weight and capacity should be so co-related to the standard measure of length that the whole system should be one and inter-dependent." That appeared to him (Mr. Mudd) to be the core of the whole subject, and any intelligent man who would sit down and read those words over and over again with models before him, till illustration after illustration brought one meaning after another to the words on his tongue, would rise up from the study prepared to admit that the simplicity and perfection of the metrical system marked it as a work of genius, and he would acquire a new-found disgust at the out-of-date system of weights and measures they still adhered to in this country. Another important way to look at it was the advantage of intercommunication which it set up. A good story was told of William Makepeace Thackeray. Travelling in a foreign land in which he happened to be more facile with his pencil than his tongue, after making frantic efforts to be understood as to his dinner, he hit upon the plan of sketching a leg of mutton, and so he had his dinner in which a leg of mutton figured largely. Again, a friend travelling in Russia forget the word for water and hit upon the plan of writing H_2O, and was quickly understood. These were qualitative means of communication: one pictorial, and the other by symbols understood by scientific men all over the world. The next step, short of a universal language, is the quantitative expression for things, and this they would be in possession of in their dealings with the bulk of the civilised world when they adopted th metric system of weights and measures. When the rest of Europe wakes up to the fact that the English language is the one that should and must be universally spoken, they would feel compensated for having had to adopt their system of quantitative expressions. Then, if, as engineers and shipbuilders, they were to look at the

practical side of the question, they would ask themselves, What would the change involve in the workshops, and would the cost be great? The answer, he thought, was in a fairly narrow compass, but every trade would have to answer it in accordance with the exigencies of its own particular case. He did not think the difficulty would be greater in any trade than in those of engineering and shipbuilding. Taking a marine engine works as an example, he thought that in the drawing office a month's practice would enable intelligent draughtsmen to think in the metric system, and then all would be easy, without any extra expenditure of brain power or money outlay. Then, in the pattern shop, it was quite as easy for a patternmaker to work to one rule as another. The foundry it would not affect, for they worked to the pattern. The boiler shop would not be affected either, except in so far as the new measures affected their machines. In the engine shop they found concentrated the bulk of the difficulty of the change. What was the difficulty in the engine shop? Well, first there was the question of gauges. It seemed to him that all existing gauges would be put on one side and kept for repair work that had been made to English measures, and a new set of size gauges would be made for all new work. After the gauges there was the question of screw threads. As English measures would not correspond satisfactorily with metric measures, it was clear the relation of diameters to thread pitches would require some adjustment so as to adapt it satisfactorily and permanently to the metric system, and in his opinion it would be best to treat the screwing tackle in the same way as the gauges, setting aside the old tackle for use on repairs, and adopting a new set of tackle for new work. Then there were the lathes and screw-cutting machines. These would need some changes, generally unimportant, and consisting mainly in new change wheels to enable the new system of threads to be cut by the old leading screws. It seemed to him (Mr. Mudd) that the enormous advantages—national advantages—offered by the change of system were well worth the trouble and probable cost. They should not forget that the cost was a "once for all" expenditure for an everlasting advantage. He did not think there was anything in all this that bulked up to what one might call a question of first magnitude, except that of the screw threads; and it was in the solution of just such a difficulty that the services of an institution like this became invaluable. For the question is only difficult inasmuch as it is difficult to get all parties interested to agree upon one standard. If this Institution would consider the subject carefully and take steps to induce kindred institutions to do likewise, a comparison of notes amongst them should speedily result in the establishment of an

international standard of screw threads, as suggested by Mr. Baines. The more the matter was looked into the less difficult did it appear, and with their indulgence he would like to go into that part of the question a little more fully. The Whitworth thread was now so largely used in this country that one's first thought was to suggest that it be retained as far as form of thread goes, and that in regard to pitch it be merely modified sufficiently to accommodate itself to metric measure. This would probably commend itself at first sight to English engineers, because the suggestion was based upon a thread that had been a good friend in the past, and because it rested upon the reputation and genius of an engineer so universally respected as Sir Joseph Whitworth. They ought scarcely, he thought, to stop just there, however, in the enquiry; because, in the first place, however slight a change they made in screw threads, there would of necessity be involved the provision of new tackle, so that the field was fully open just at the moment when they were changing to the metric system for any change they might like to make; and, secondly, because the two other standard threads largely in use outside of this country differed slightly in the angle of the thread from Whitworth's. He alluded to the Sellers thread, largely used in America, and the French Admiralty thread, both of which had an angle of 60 degs., whereas 55 degs. was the angle of Whitworth's thread. The angle of the thread practically determined its depth, and therefore there were left two characteristics of the first importance in a thread, viz., the pitch and the angle of thread. Now, it unfortunately happened that there was a kind of triangular duel between the three extensively used threads he had named, for whilst the Sellers thread was the same in pitch as the Whitworth (except in a few special instances), its angle was 60 degs. instead of 55 degs., and whilst the French Admiralty thread was like the Sellers thread in angle, its pitch was regulated to fall in with metric measure. He had had a diagram prepared to illustrate this (see Plate LXIX.). At one part were shown the 55 degs. Whitworth thread, and the 60 degs. Sellers and French thread. At another part the relation between diameter of bolt and screw pitch was shown, the dotted lines with white circles representing the Whitworth thread, the thin full lines with shaded circles the Sellers variation therefrom, and the black lines and circles the French Admiralty threads. That he might find out whether Sir Joseph had any very urgent reason for the adoption of the curious angle of 55 degs. in preference to the more natural one of 60 degs., he had looked up his original paper on the subject, read before the Civil Engineers in 1841, and found that was not the case. It was

pitched upon merely because it was an average of the angles in use amongst the various shops at that time, and was chosen in that spirit of conciliation and compromise which was the basis of the whole scheme, and which proved Sir Joseph to be not only a great engineer, but possessed of a keen insight into human nature. The paper indeed was very interesting, from the fact that it might have been written to-day in the interest of a compromise for the establishment of an international thread, just as it was then for that of a national one. He would like to quote one or two short extracts from it, to make it perfectly clear how Sir Joseph (then Mr.) Whitworth arrived at the thread that went by his name. He said :—

As yet there is no recognised standard. This will not be matter of surprise, when it is considered that any standard must be to a great extent arbitrary. It is impossible to deduce a precise rule from mechanical principles, or from any number of experiments. On the other hand, the nature of the case is such that mere approximation would be unimportant, absolute identity of thread being indispensable. It is by no means evident what may be the precise formation most advantageous under all circumstances. No exact data of any kind can be obtained for calculation, and the problem will be found to be capable only of approximate solution. . . . There are three essential characters belonging to the screw thread, viz., pitch, depth, and form. In the selection of the thread considerable latitude of choice will be found to prevail with reference to all the characters. No definite rule can be given for determining any one of them. Choice must be guided rather by discretion than by calculation. . . .

After showing how one character limited or modified another he said :—

Such being the variety and vagueness of the principles involved in the subject, a corresponding latitude might naturally be expected in their practical application, and accordingly we find, instead of that uniformity which is so desirable, a diversity so great as almost to discourage any hope of its removal. The only mode in which this could be attempted with any probability of success would be by a sort of compromise, all parties consenting to adopt a medium for the sake of common advantage. The average pitch and depth of the various threads used by the leading engineers would thus become the common standard, which would not only have the advantage of conciliating general concurrence, but would in all probability be nearer the true standard for practical purposes than any other. . . .

He then explained that—

A collection of bolts from various shops was made and the averages carefully taken, $\frac{1}{4}$ inch, $\frac{1}{2}$ inch, and $1\frac{1}{2}$ inches being taken as fixed points of a scale by which the intermediate sizes were regulated. The scale was afterwards extended to 6 inches.

Also—

It will be remembered that the threads, of which the table shows the average, are used in cast iron as well as wrought, and this circumstance has no doubt had its

effect in rendering them coarser than they would have been if restricted to wrought iron. . . . The mean of the variations of angle in 1 inch screws was found to be about 55 degs. As it is desirable the angle should be constant, the angle of 55 degs. has been adopted throughout the entire scale.

Instead, therefore, of feeling that Sir Joseph must have proved by scientific investigation and practical experiment that the angle of 55 degs. was essential or in any way preferable to 60 degs., they were left to feel that in making any change of thread to suit metric measure, they might breathe freely whilst contemplating a change to 60 degs. angle with a view to making the new thread identical with the other two now in use in this important particular. Also, it was well to note what Sir Joseph said about the influence of cast iron threads on the coarseness of the pitch. Cast iron threads were little used now, and many English engineers had long abandoned the very coarse threads of bolts over 1½ inches diameter in the Whitworth scale, making the six threads per inch of the 1½ bolt suffice also for all sizes of bolts larger than 1½ up to even 6 inches. This was shown by the black dot and dash line on the diagram (Plate LXIX.). At their own works this plan had been carried out from the first, and with, they thought, very beneficial results. The French Admiralty thread, apparently the only one deserving the name of a standard thread which at the same time conformed to metric measure, was on the whole rather finer in pitch than the Whitworth, and it had been devised so as to make the same number of threads suit for two or three adjacent diameters of bolts, thus economising the cost of dies. The French Minister of Marine had quite recently taken a step that was likely to result in this thread being universally adopted in France, in place of the confusion of threads that had till then prevailed in that country. The Americans were agitating wisely for the adoption of the metric system, and no more fitting opportunity could be had for the arrangement by mutual agreement of a standard thread for all countries. He did not want to go so far as to definitely suggest the direction in which such a compromise might be made, but he did want to show three things:—(1) That the question of screw threads was intimately bound up with the question of the adoption of the metric system. (2) That it would be a most important and highly desirable public service for this Institution to endeavour to get the co-operation of kindred institutions in this and other countries in the establishment of an agreement in this matter. (3) That the case, when looked into, presented little difficulty, and could readily be adjusted if approached in the spirit of a true attempt to arrive at an international standard. He would close his remarks with

the expression of an ardent wish that the Institution would not only help on the cause of the speedy adoption in this country of the metric system by a suitable resolution, but would forthwith appoint a committee to make a definite move in the direction of an international standard of screw threads conformable to that system of measurement.

Mr. Ralph Tweddell wrote on the subject as follows:—

DEAR MR. DUCKITT,

While I quite agree with, and had I been able to be present, should have supported, Col. Robson's resolution, I think that this Institution will have to take a very much more decided course of action if any real advance is to be made in introducing the metric system. I have not much confidence in the effect of the report, even if favourable, of a Select Committee, which, as a rule, is only constituted in order to get a troublesome subject out of the way. As doubtless many members are aware, a Bill for legalising the use of the metric system in this country, introduced by Mr. William Ewart, was read a third time and passed on the 28th of June, 1864. It was, however, only a permissive one, and thirty years have elapsed since then. Not much good is therefore to be expected from Parliamentary action alone. If it be true, as we have been told, that a Government only exists to carry out views pressed upon them by the people, it is evident that the initiative must come from them, and if we engineers want the decimal system, we must commence to use it among ourselves and in our daily work; and if the advantages are such as we think they will be, then other trades will follow, and by this means a steady mechanical pressure will be brought to bear which no Government, irrespective of party, could long resist.

There can be no question at all as to the enormous advantage the adoption of the metrical system would be, not only in simplifying our own calculations, but especially when dealing with foreigners. It was all very well twenty-five or thirty years ago, when many of us can remember our foreign friends and customers travelled unheard of distances and came to our offices and works. It may not be so with all, but I can answer for this, that the tables are now turned, and it is we who now travel unheard of distances and go to their works and offices; and when we get there what do we find? that they are supplying machinery often, but by no means always, of an inferior kind, and in many cases at higher prices, to firms who used to come here, and not only that, but to our own colonies. This is the subject of common remark amongst engineers like myself,

whose business it is not only to initiate and introduce new systems of working, but to assist merchants and manufacturers in finding new markets for their products. I say it is a very common experience that we sometimes never even obtain an answer to tenders which have involved a great amount of time and expense to prepare. I am convinced that one great cause for this is our barbarous jumble of dimensions which do not convey to the intelligent foreigner as much meaning as the Newcastle fitter's somewhat approximate dimension of "6½ inches of string, the length of his thumb, and a bit of chalk!" I should suggest that a small working committee be formed of members of this Institution, and that a grant of money be made to enable them to visit, or send some one to visit, those countries which have changed their system to find out how it actually works out in shop practice, and then report to a future meeting; possibly this could be done jointly with the Decimal Association. The question is, of course, a very large one, but up to the present, while many preach, none of us practise.

If locomotive engineers, steamship builders, and electrical engineers would only send out their specifications in terms of metres, and if users of machine tools would only buy them on the same basis, it would be a very short time before every one was decimalised. I think that a report from some such committee, backed up by this Institution, would have great weight, and we could ask the co-operation of other influential scientific societies. The inch and foot rules divided into $\frac{1}{10}$ths is, I think, really only adding to the complication, and up to the present their use has hardly made any progress. The inch also is too small a unit. Once get the metre introduced, and the rest will easily follow. We must not, I think, trouble about details at present; screws and screw threads and so forth will adapt themselves. Once substitute the metre for the two-foot rule, and the rest will follow naturally.

Yours faithfully,

R. H. TWEDDELL.

Mr. W. H. ATHERTON said it seemed to him that no one who had carefully studied Mr. Baines's paper could doubt the immense superiority of the metric system over their own troublesome collection of units. Everybody admitted that it was much easier to multiply and divide by 10 and powers of 10 than by such awkward numbers as they were called upon to use. Everyone also agreed that an international system of weights and measures was a thing greatly to be desired. It might well be asked then, Why don't they adopt the metric system? Two main

obstacles stood in the way. These were :—(1) The unfamiliarity of the public with regard to it, and the unwillingness of the men to take a little trouble in learning it. (2) The unavoidable expense attending its adoption, and the unwillingness of the masters to incur this expense. The important question they had to consider was, How can these two difficulties be faced? As regarded the first point, their duty was to remove this unfamiliarity, and perhaps prejudice, on the part of the men; to show them the beauty and simplicity of the system; and to teach them how to use it. The question was, How could this be done? It could be done, he thought, by machinery, and, luckily, by machinery already in existence. The science and art department, the great educational institution of the masses, was quite competent to perform it. What was needed was the addition to the syllabuses of machine drawing, theoretical and applied mechanics, and steam, of some such clause as the following :—"A knowledge of the metric system of weights and measures will be required of all students, and a proportion of questions will be set in metric units. In machine drawing, one of the examples to be drawn will be dimensioned in metric units, and the millimetre scale appended must be worked to." A little extra trouble, both to teachers and taught, would be the immediate consequence, but the benefit that would ultimately accrue was obvious. Their teachers and apprentices would soon become quite familiar with the new system, and able to use it in practical work. These would speedily leaven the whole mass. Further, in all their colleges where engineering was taught students should be accustomed to the use of metric units on a large scale, in preparation for the inevitable day when their use must become general. The metric system should not be confined merely to the chemical and physical departments. It contained not only the milligram, but also the tonne, which was almost identical in value with their own ton, and just as well adapted for engineering calculations. Some other ways of rendering the system familiar to the profession generally were:—(1) In books and articles translated from French, etc., into English, to leave the quantities still expressed in metric units and to enclose their English equivalents in brackets. This is often done in our technical journals already. A similar practice might with advantage be adopted in all papers read before scientific societies, until such time as we are able to dispense with the old units. (2) To fix on all steam boilers an additional pressure gauge, graduated in kilogrammes per square centimetre. On this matter of pressures it is useful to remember that a kilogramme per square centimetre [kg. per cm.^{2}] corresponds roughly to

the pressure of an atmosphere, *i.e.*, 15 lbs. per square inch. More accurately 10 kg. per cm.^{2} = 142 lbs. per inch^2. (3) To graduate the automatic "penny-in-the-slot" weighing machines at our railway stations in kilogrammes, as well as in terms of that very unscientific unit the stone. (4) To carry about in the pocket a small steel tape measure like this (sample shown), graduated on one side in inches, on the other side in millimetres; and to take measurements in terms of both units. (5) To often examine general and detail plans of familiar objects, dimensioned in metric units. (6) To use, for plotting curves, paper in 2 by 2 or 5 by 5 millimetre squares, instead of the usual 10ths of an inch. By such methods the first difficulty, that of unfamiliarity, could be overcome. There yet remained for consideration the second difficulty, that of expense. First, as to the drawing office. Here the cost of new tools would not be great. They should require little else than new scales, numerical tables, and formulæ constants. During the transition period the new way of thinking would be troublesome, and dimensions would have to be stated in terms of both millimetres and inches. New designs would be got out in metric units. Second, as to the shops. Here the cost of new tools would be much more serious. The alteration would involve new gauges of every kind, perhaps new screwing tackle and other standard tools, new guide screws for some of the lathes,* fresh sets of weights for weighing scales, and new graduations of platform weighing machines. But some of the old tools and gauges would still be required, as Mr. Baines remarked, for repair jobs. Given these new appliances, however, their workmen would work as easily in millimetres as in inches. It cannot be denied that both the inconvenience and expense attending the change would for a time be great. But it seemed clear that just as the Great Western Railway Company with their broad gauge were compelled, first of all to lay down an additional narrow gauge line, and at length to discard the broad gauge altogether, so they, for the sake of uniformity with their neighbours, would have to run two sets of gauges side by side in their shops, until

* Except for very short lathes, it would be cheaper to cut a few new odd-sized change wheels than new guide screws. To cut a screw of 1 cm. pitch with a guide screw of half-inch pitch we should require a train of wheels in the ratio 0·3937 to 0·5, *i.e.*,

$$\frac{31}{50} \times \frac{127}{100},$$

with an idle wheel on an extra stud. A close approximation, giving more convenient wheels, is—

$$\frac{48}{100} \times \frac{82}{50},$$

whence the wheels required to cut any other metric pitch can easily be deducted.

such time as they could dispense with the old system entirely. The cost of altering shop tools would not be anything like so great as the cost of altering the rolling stock of a great railway. Whose duty was it to take the lead? The Government authorities, he thought. If the Admiralty were to adopt the practice of specifying that the machinery of warships must be made to metric units a great step would be taken towards the general adoption of the system for machinery of all kinds. But if the Government refused to move in the matter, why not follow the example set by Messrs. Willans & Robinson without waiting for any new Acts of Parliament? If they rejected this system, what was the alternative? If they persisted in using a numerical language, which their more enlightened neighbours rightly regarded as antiquated and absurd, they must be left behind in the struggle for supremacy, and fall to the rear in the march of civilization. The metric system might not be ideally perfect. Perhaps it would have been better if its framers had taken a value of the metre, such that the well-known dynamical constant g would have been 10, in latitude 45 degs., instead of 9·8 as at present. But it was certain that the relation of the other units to the fundamental one was the best and simplest that their decimal system of numeration admitted of. Let them then take and welcome the metric system in its entirety just as it stood, and be thankful that they had so excellent a system already to hand, one that had been tested for nearly a hundred years and not found wanting. He thought that the sooner the system was adopted the better, and that they ought to use their utmost endeavours to bring about this much to be desired end.

Mr. G. H. Baines, in reply, said he wished to acknowledge the support he had received from members in connection with the suggestions in his paper. He had proposed and carried unanimously in the Durham County Council a resolution of the character before that Institution. Last week, in London, at a meeting of the Association of School Boards of England and Wales, a similar motion was carried, and that the children should be more carefully taught decimals and the metric system of weights and measures. With reference to the remark of the last speaker as to the difficulty to workmen, he was sure, from enquiries, that would be very slight. The Trades Congress four years ago distinctly recommended that the metric system should be adopted, and two of its members sat on the House of Commons Committee. He had been present at a sitting of the Committee the previous week, and had been informed that the evidence was greatly in favour of the adoption of the change. It only wanted

a push, a unanimous push from various quarters, to make the Government take it up. If the Government will lead by using it in their own works, other trades would be willing to follow. He appealed to each member to use his influence to promote the gradual use of the system.

The PAST-PRESIDENT now put the motion as amended by the Council to the meeting, and it was carried *nem. con.*

The PAST-PRESIDENT moved a vote of thanks to Mr. Baines for putting the subject so ably before the Institution. He was sure it was an enlightenment to them all.

The proposal was adopted by acclamation.

Mr. BAINES acknowledged the compliment, and said that in facing foreign competition they had the greatest need to adopt the system.

NOTE.—The Select Committee of the House of Commons has reported that it is desirable that the Metric System be made (*a*) permissive at once; (*b*) compulsory in two years after passing of an Act.—EDITOR.

July 1*st*, 1895.

CLOSING BUSINESS.

CONSTITUTION AND BYE-LAW ALTERATIONS.

The PAST-PRESIDENT, on behalf of the Council, moved that the following alterations and additions be made to the Articles of Constitution and the Bye-Laws :—

NOTE.—Proposed alterations are in italics.

CONSTITUTION.

Add to Constitution VIII.—" *All such compositions shall be deemed to be capital moneys of the Institution.*"

BYE-LAWS.

Bye-Law 6.—For " first of June " read "*first of August*," as under :—

Bye-Law 6.—All subscriptions shall be payable in advance, and shall become due on the 1st of *August* each year. Any Member, Associate, or Graduate wishing to retire from the Institution shall continue to be liable for his annual subscription until he shall have given formal notice of his retirement to the Secretary, which notice must be given on or before the 31st of August in each year. Application for membership may be made at any time during a session, and the subscription shall cover the membership up to the 1st of *August* following.

Add to Bye-Law 28.—" *The President shall, ex-officio, be a member of all Committees.*"

Add to Bye-Law 31.—" (4) *A Graduates' Award Committee, to consist of five members.*"

Bye-Law 43.—For " the 31st of May," read " *the 31st of July.*"

Insert the following new bye-law after Bye-Law 44 :—

" *The Finance Committee may, with the consent of the Council, invest in the names of the appointed Trustees of the Institution any moneys, not immediately required for the purpose of the Institution, in or upon any approved securities.*"

The alterations were agreed to.

EXECUTIVE MEMBERS.

The PAST-PRESIDENT declared that the result of the ballot for the executive during the ensuing year was as follows:—President, Ald. Thos. Richardson, J.P., Hartlepool; Vice-Presidents, Mr. John Gravell, Sir Wm. Gray, J.P., and Mr. D. B. Morison; Members of Council, Messrs. W. H. Dugdale, Col. T. English, J. B. Furneaux, Robert Readhead, J.P., and John Walker; Hon. Treasurer, Mr. G. E. Macarthy.

The PAST-PRESIDENT moved the re-election of Mr. R. W. Sisson as Auditor, this was seconded by Mr. W. G. SPENCE, and carried.

THANKS TO RETIRING MEMBERS OF COUNCIL.

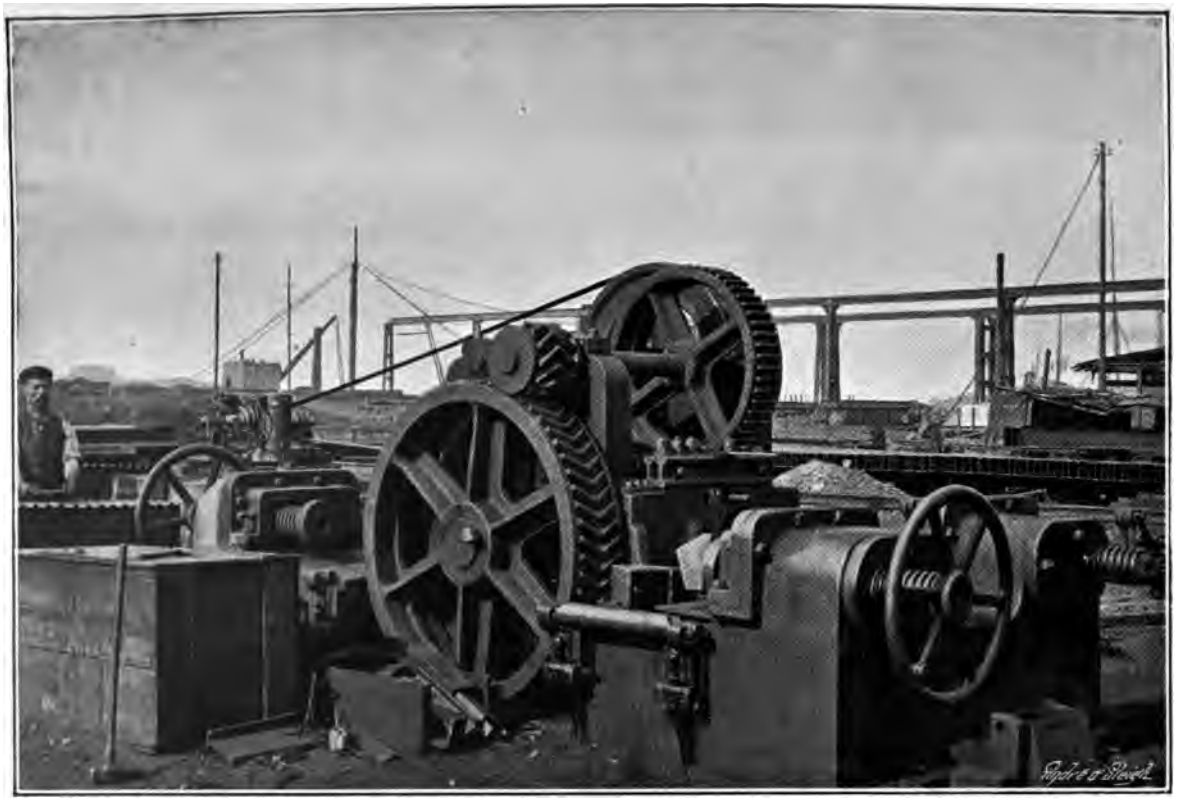
Mr. J. G. JORDAN moved "That the best thanks of the Institution be given to the retiring members of Council for their services on the Board." He was sure all members of the Institution appreciated their desire to carry on the business of the Institution successfully, and that they would not regret that their retirement gave an opportunity to other members of taking an active part in the affairs of the Institution. The rule was a very good one, and they had always the consolation that at the end of twelve months they had the opportunity of being re-elected.

Mr. ARNISON seconded the motion.

The vote was carried by acclamation.

CLOSE OF THE SESSION.

The PAST-PRESIDENT said he had only now to declare the present session closed. He was very well pleased to see the way members had held out to the end of a long sitting. They were better off than the American Congress. He was there recently and saw only three or four in the House. It was adjourned for a quarter of an hour to get sufficient members forward to form a quorum and close the Congress. He declared the eleventh session of the Institution closed.



LARGE STRAIGHTENING MACHINE DRIVEN BY 3½ HORSE-POWER ELECTRIC MOTOR, AT THE WORKS OF MESSRS. DORMAN, LONG, & CO., MIDDLESBROUGH.

To illustrate "President's Inaugural Address."

HORSE-POWER ELECTRIC MOTOR DRIVING A DOUBLE PUNCHING MACHINE AT THE WORKS OF MESSRS. DORMAN, LONG, & CO., MIDDLESBROUGH.

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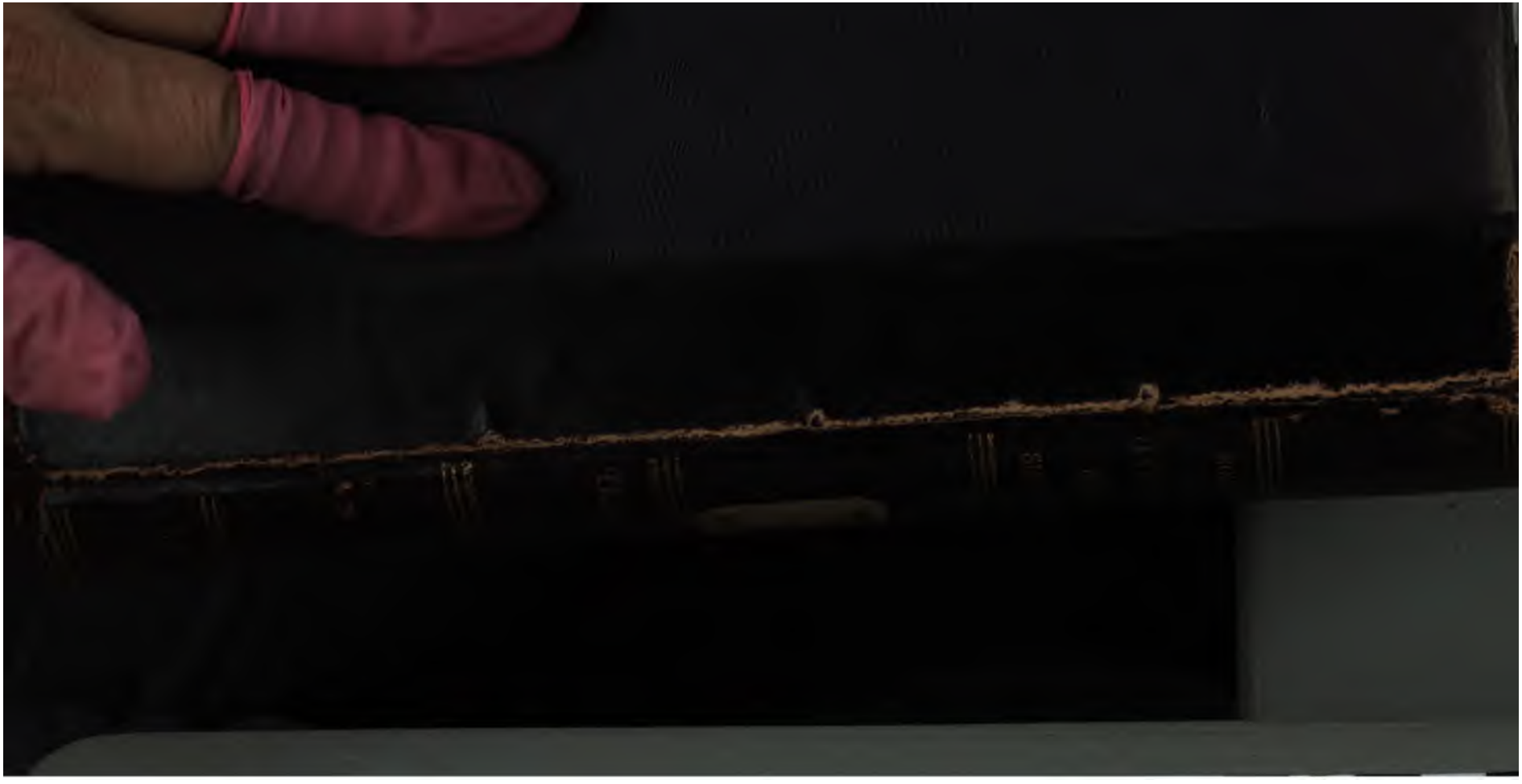
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